NOVEMBER 1961

# Journal

VOL. 53 • NO. 11

## AMERICAN WATER WORKS ASSOCIATION

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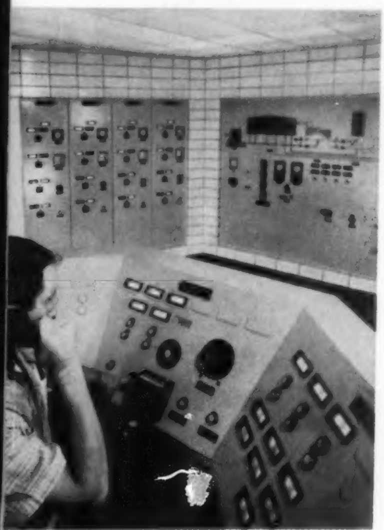

*Automated flowchart centralizes control of water plant operations at South Pittsburgh*

Journal

AMERICAN WATER WORKS ASSOCIATION

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November 1961

Vol. 53 No. 11

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**AWWA ANNUAL CONFERENCE**

**Philadelphia, Pa. June 17–22, 1962**


# *Coming Meetings*

## AWWA SECTIONS

### Fall 1961

**Nov. 13–15**—North Carolina Section at George Vanderbilt Hotel, Asheville. Secretary, T. Z. Osborne, Asst. Director of Public Works, Box W-2, Greensboro.

### Spring 1962

**Jan. 23**—New York Section, Luncheon Meeting at Statler-Hilton Hotel, New York, N. Y. Secretary, Kimball Blanchard, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

**Feb. 7–9**—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, Chester H. Canham, State Board of Health, 1330 W. Michigan St., Indianapolis 7.

**Mar. 15**—New England Section, at Statler Hotel, Boston, Mass. Secretary, Ralph M. Soule, San. Engr., State Dept. of Public Health, 511 State House, Boston, Mass.

**Mar. 28–30**—Illinois Section, at Sheraton-Towers Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engineer, Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

**Apr. 5–7**—Montana Section at Bozeman. Secretary, A. W. Clarkson, Div. of Environmental Sanitation, State Board of Health, Helena.

**Apr. 11–12**—New York Section, at Manger DeWitt Clinton Hotel, Albany. Secretary, Kimball Blanchard, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

**Apr. 12–13**—West Virginia Section, at Hotel Morgan, Morgantown. Secretary, Thomas J. Blair III, Kelley, Gidley, Staub, Inc., 5418 Mac Corkle Ave., S.W., Charleston.

**Apr. 15–18**—Southeastern Section, at Wanderer Resort Motel, Jekyll Island, Ga. Secretary, N. M. deJarnette, Robert & Co. Assocs., 96 Poplar St., N.W., Atlanta, Ga.

(*Continued on page 8*)

# IOWA Valves and Hydrants

## *by the carload to meet San Jose Water Works' growing requirements*

Glimpse of new subdivision of San Jose, California. City has grown from 95,280 to 202,571 in past ten years.

Unloading scene as IOWA hydrants are delivered by the carload to San Jose Water Works.

Two IOWA gate valves and a new hydrant being installed. Hundreds of these Iowa products are important components of San Jose's modern system.

Carloads of IOWA gate valves and hydrants were purchased by the San Jose Water Works (an investor-owned, private company established in 1866) for installation in their rapidly expanding system which serves seven cities and unincorporated areas in Santa Clara County, California.

Over 17,000 new water service connections were made in the last two years along 1200 miles of water mains to help care for a metropolitan population (Approx. 306,000) which has doubled since 1950.

IOWA products were selected to be a part of the San Jose Water Works' growth because of their proved dependability with minimum maintenance and assurance of long-life performance.

Every year more and more IOWA valves and hydrants are installed to serve the needs of growing communities like San Jose. Experience shows that IOWA products have that extra quality of materials, that extra-precise fitting and assembly that makes for longer life and easier maintenance.

*Let us send you details on the complete IOWA line*

**IOWA VALVE COMPANY**
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## Coming Meetings

(Continued from page 6)

**Apr. 24–26**—Nebraska Section. Secretary, Charles W. Durham, Cons. Engr., Henningson, Durham & Richardson, 2963 Harney, Omaha.

**Apr. 27**—California Section, at Ahwahnee Hotel, Yosemite Valley. Secretary, Frank F. Watters, Hydr. Engr., Public Utils. Com., State Bldg., Civic Center, San Francisco.

**Apr. 29–May 3**—Canadian Section, at Royal York, Toronto, Ont. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

**May 2–4**—Kansas Section, at Lassen Hotel, Wichita. Secretary, F. Harry McBride, Sales Engr., B-I-F Industries, 2108 W. 75th St., Prairie Village.

**May 3–5**—Arizona Section, at Pioneer Hotel, Tucson. Secretary, A. D. Cox Jr., Secy. & Comptroller, Arizona Water Co., Box 5347, Phoenix.

**May 30–June 2**—Pacific Northwest Section, at Olympic Hotel, Seattle, Wash. Secretary, Fred D. Jones, W. 2108 Maxwell Ave., Spokane, Wash.

### OTHER ORGANIZATIONS

Nov. 13–17—APHA, Cobo Hall, Detroit, Mich.

Nov. 26–Dec. 1—ASME Winter Annual Meeting, Statler-Hilton Hotel, New York, N.Y.

Nov. 27–Dec. 1.—28th Exposition of Chemical Industries, Coliseum, New York, N.Y.

### SHORT COURSES

Nov. 13–17—Training course on "Radionuclides in Water," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

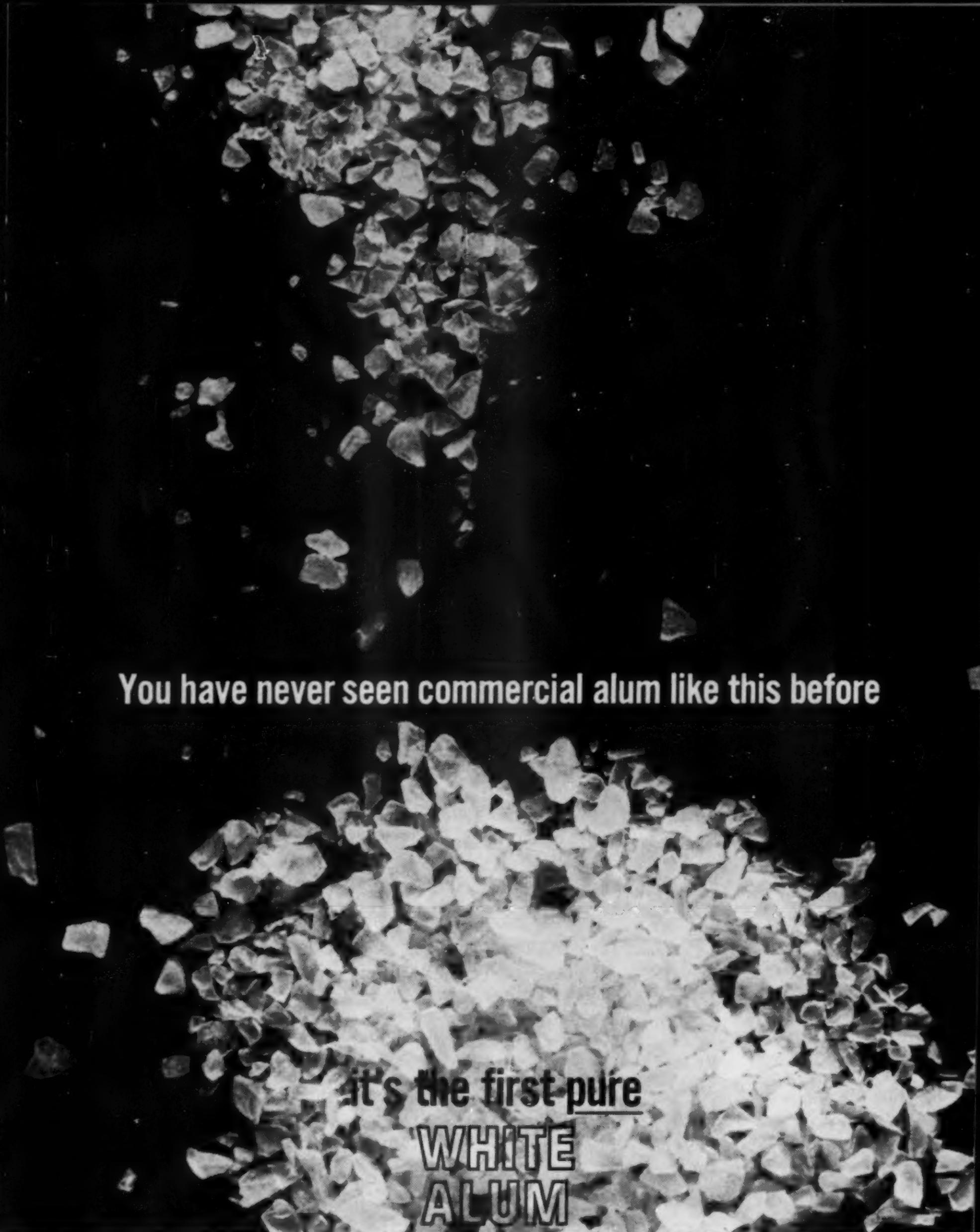
Dec. 4–15—Training course on "Chemical Analyses for Water Quality," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

#### 1962

Feb. 5–9—Training course in "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Feb. 13–14—"Water Distribution Systems," the 4th Sanitary Engineering Conference, Urbana, Ill., cosponsored by the Illinois Dept. of Public Health and the Dept. of Civil Engineering, Univ. of Illinois. Write: C. W. Klassen, Chief San. Engr., Dept. of Public Health, Springfield, Ill.

Feb. 27–28—Underground corrosion short course, at Purdue University, Lafayette, Ind., cosponsored by the Indiana Section, AWWA. Write: Ray C. Andrew, Conference Coordinator, Div. of Adult Education, Purdue University, Lafayette, Ind.


You have never seen commercial alum like this before
it's the first pure
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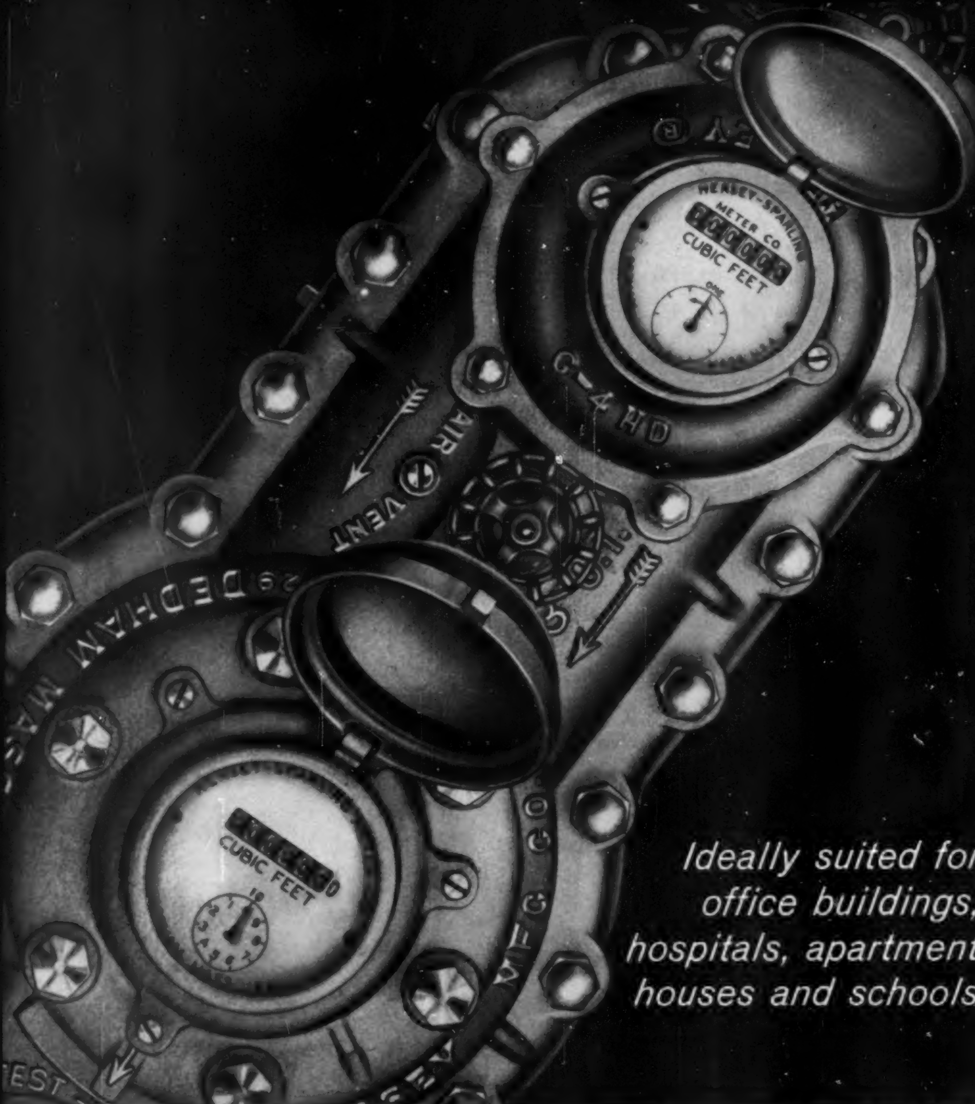
ALUM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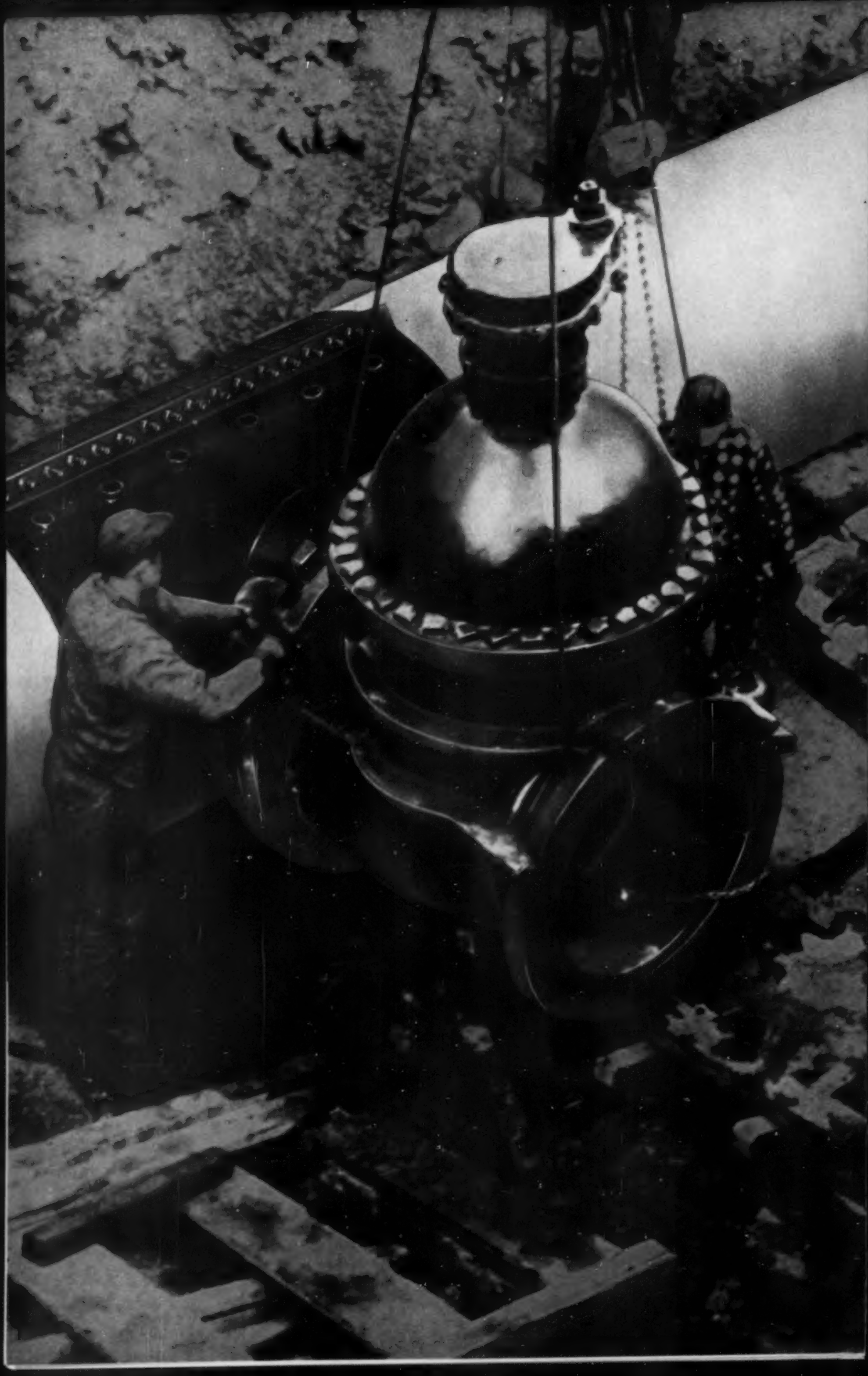

# a snap to tap... concrete pressure pipe

## LARGE OR SMALL

Thousands upon thousands of permanent pressure taps made in concrete pressure pipe demonstrate conclusively the ease and efficiency with which this type of pipe may be tapped for small service connections or larger outlets.

Taps from $\frac{5}{8}$" to 42" have been made under pressure in pipes varying in diameter from 10" to 150", without damage to the pipe's structure or interruption of service. Tapping is accomplished with conventional and commercially available equipment.

The fine safety record of this tapping operation and the equally high safety record of the pipe itself, makes CONCRETE PRESSURE PIPE the ideal medium for distribution mains, particularly in congested areas where pipe failure is synonymous with disaster.

You can always depend on CONCRETE PRESSURE PIPE.

WATER FOR GENERATIONS TO COME

**Concrete PRESSURE Pipe**

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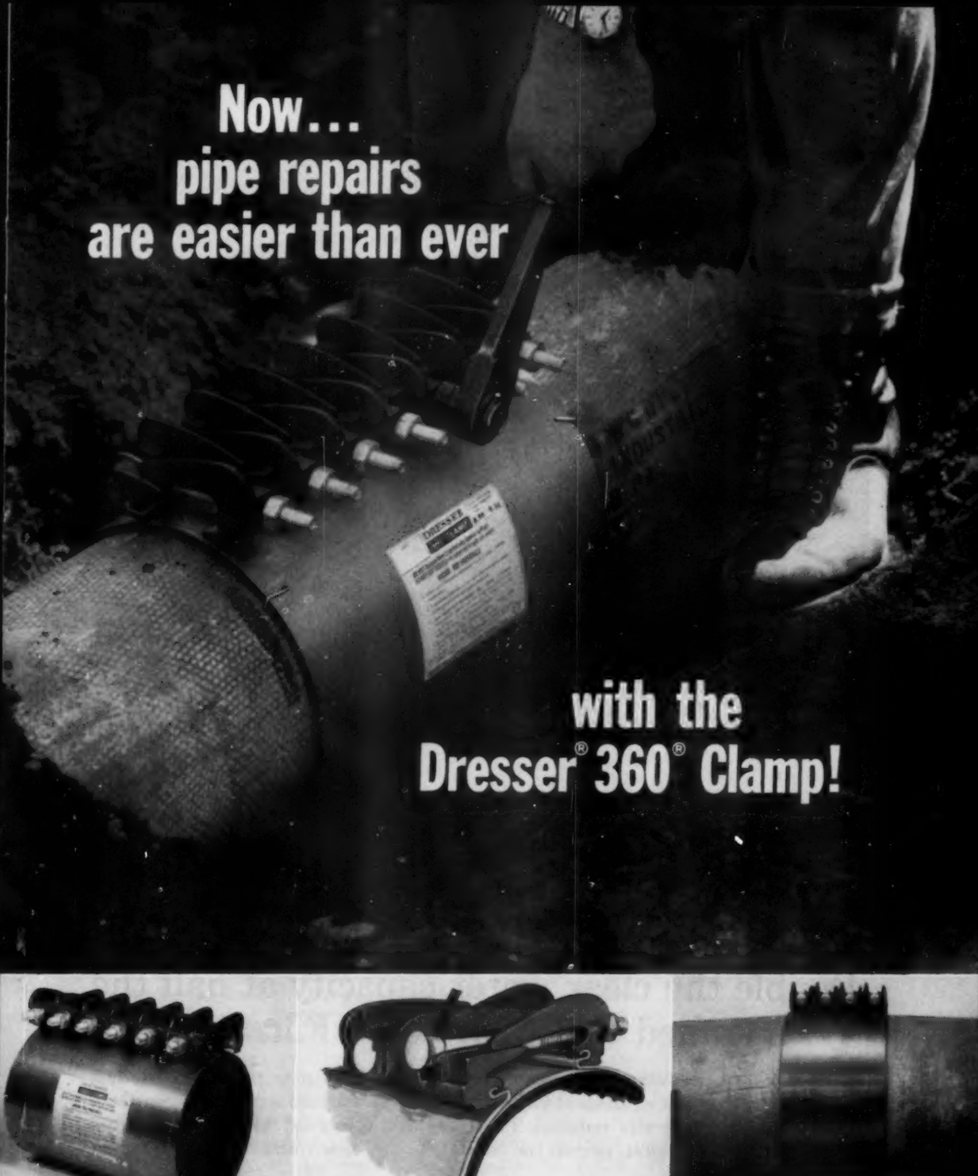
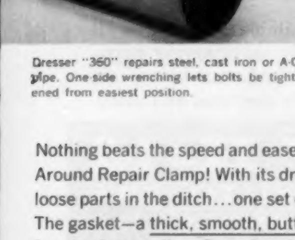
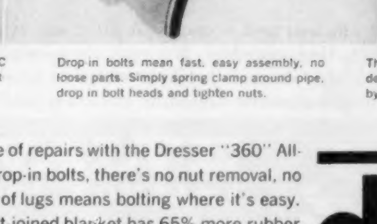
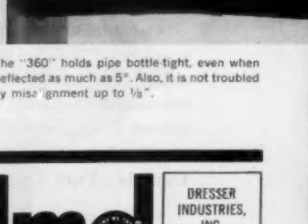


Dresser "360" repairs steel, cast iron or A-C pipe. One-side wrenching lets bolts be tightened from easiest position.



Drop-in bolts mean fast, easy assembly, no loose parts. Simply spring clamp around pipe, drop in bolt heads and tighten nuts.



The "360" holds pipe bottle-tight, even when deflected as much as 5°. Also, it is not troubled by misalignment up to ⅛".

Nothing beats the speed and ease of repairs with the Dresser "360" All-Around Repair Clamp! With its drop-in bolts, there's no nut removal, no loose parts in the ditch...one set of lugs means bolting where it's easy. The gasket—a thick, smooth, butt-joined blanket has 65% more rubber for absolute sealing. Doesn't wrinkle. The Dresser "360" provides ⅜" adjustment—fits more pipe sizes, means fewer clamps to stock. For details on the "360", or any of THE DRESSER LINE for coupling or repairing pipe — write us, or call your nearest Dresser Distributor.

dmd
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MANUFACTURING DIVISION
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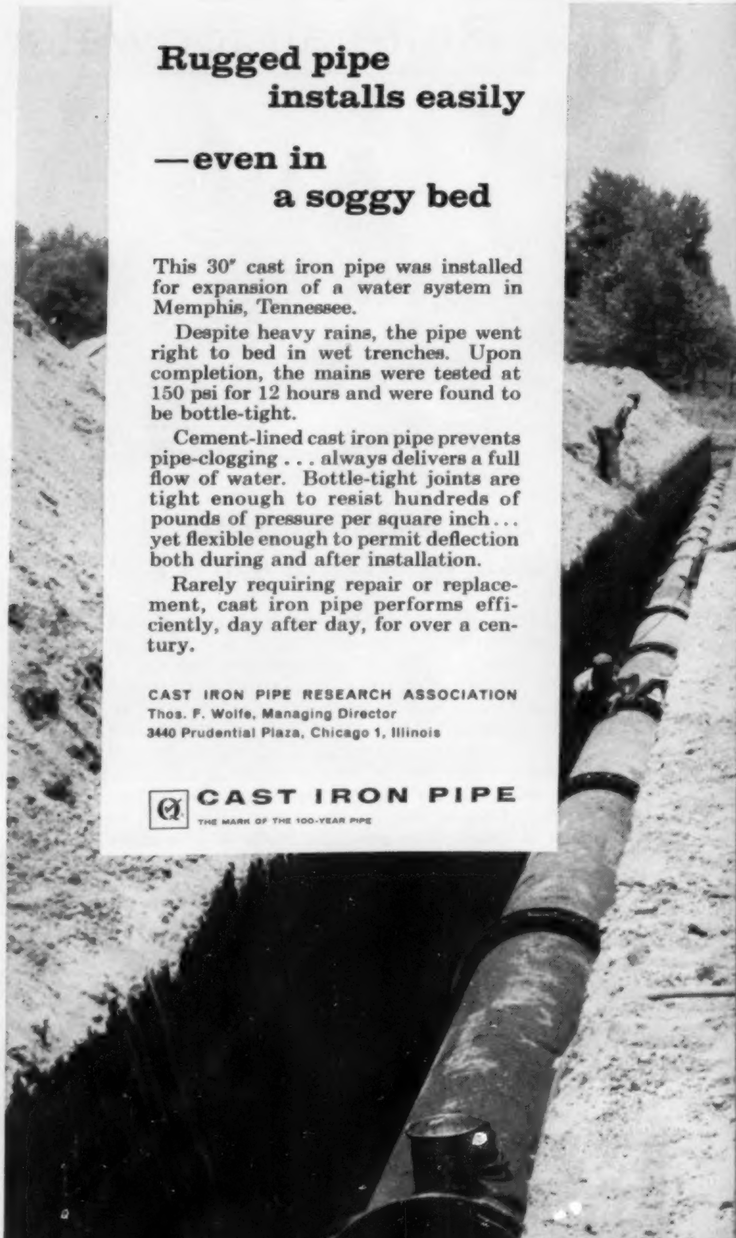
Rugged pipe installs easily
—even in a soggy bed
This 30" cast iron pipe was installed for expansion of a water system in Memphis, Tennessee.
Despite heavy rains, the pipe went right to bed in wet trenches. Upon completion, the mains were tested at 150 psi for 12 hours and were found to be bottle-tight.
Cement-lined cast iron pipe prevents pipe-clogging . . . always delivers a full flow of water. Bottle-tight joints are tight enough to resist hundreds of pounds of pressure per square inch . . . yet flexible enough to permit deflection both during and after installation.
Rarely requiring repair or replacement, cast iron pipe performs efficiently, day after day, for over a century.
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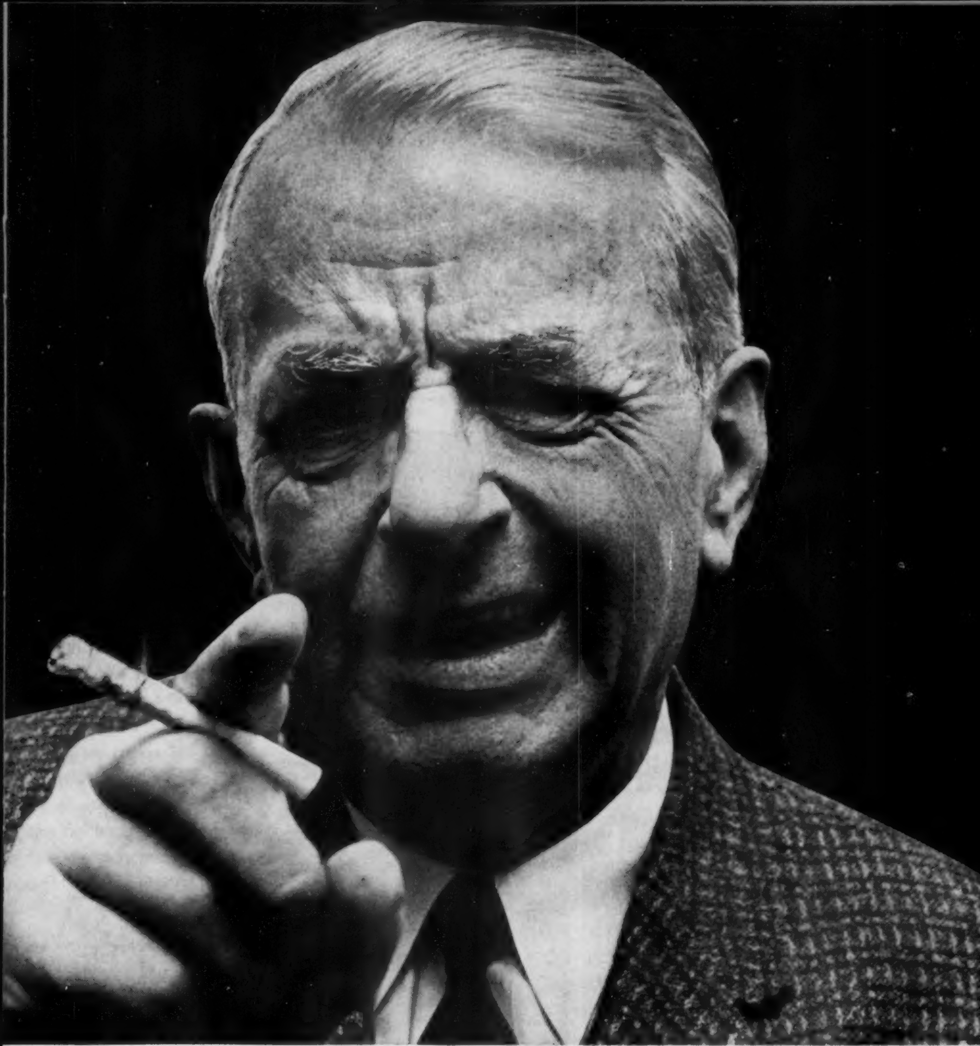
THE MARK OF THE 100-YEAR PIPE



# ACCP* BRINGS ABUNDAN GOOD WATER TO CARLSBA FROM ANCIENT DESERT REE

...OPENS WAY FOR 50 YEARS OF INDUSTRIAL GROWT

**MAIN TRANSMISSION LINE** of 33" American Concrete Cylinder Pipe extends 33,000 feet northward toward Carlsbad, just below the horizon. Portions of well-collector lines radiate from one of seven automatic pumping stations (white spot in center).

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# Adequacy in Water Utility Operations

## *A Symposium*

*A symposium presented on Jun. 5, 1961, at the Annual Conference, Detroit, Mich.*

## Introduction—*Gerald E. Arnold*

*A paper presented by Gerald E. Arnold, Gen. Supt., Water Dept., Philadelphia, Pa.*

ADEQUACY in water utility operations consists of having more service, facilities, planning, and other essentials than are necessary just to get by. To be fully adequate, a utility should be able to meet requirements under adverse conditions. For example, a pump station is adequate when it is able to meet the maximum demand with its largest unit out of service.

This adequacy must be attained in all phases of operation. As one important phase, a manager should be qualified to handle his water utility under emergency conditions in times of stress. He should also be able to resist political pressure. Consumer service should mean more than just proper pressure, quantity, and quality of water. It should include customer relations, reading, billing procedures, and some activities of public relations.

Rates should comprehend not only the present needs of the utility, but some consideration for retirement and obsolescence. Plant facilities should include necessary plant capacity to meet demands under severe conditions or with a part of a plant out of service.

Accounting practices should include the necessary statistical information to indicate to the manager the relative costs incurred by the units of his utility. With this information, he should be able to meet consumer demands for information regarding billing. Engineering records should be duplicated

for storage at remote places where they will not be lost in the event of fire or other emergency.

Planning should take into account all features of future growth in the area, including changes in population, living habits, and social customs. Public relations should be such as to give information needed to the public or the press, and to handle heavy demands for assistance in the event of emergency.

## Managerial Qualifications—*Jack A. McCullough*

*A paper presented by Jack A. McCullough, Water Supt., Dept. of Public Utilities, Colorado Springs, Colo.*

To explain the qualifications for an adequate water utility manager, it is necessary to mention the problems with which he is required to cope. In 1958, the US Business and Defense Services Administration estimated [1] that almost half of the 117,000,000 people served by public water supplies could not be sure of having enough water available to put out a major fire on a hot summer day. It was also anticipated that by 1975, water use will increase from about 160 gpcd in 1958 to 200 gpcd 17 years hence, and that the public water supplies will be serving not the 117,000,000 people of 1958, but 149,000,000 people. To meet these demands, water utilities will need to construct new facilities worth about 20 billion dollars by 1975.

It is apparent that the water utility manager has his work cut out for him. It is equally apparent that he must be a competent, well qualified, experienced administrator. The committee report on compensation of managers [2] supplies a great amount of information on the qualifications of a water utility manager. This report was based on a questionnaire sent to 1,998 water utility managers in the United States and Canada. About 52 per cent of the questionnaires were returned. All cities of 25,000 or more population were sent questionnaires. A random sampling of towns with less than 25,000 people was accomplished by contacting 1,104 of the 16,637 towns in that class.

The survey revealed that salaries of water utility managers are definitely low by present standards. Twenty-nine per cent of the respondents in the United States and 46 per cent of those in Canada received annual salaries of less than $3,500 per year. The average annual salary of all United States respondents, for managing a water utility, was $5,960; in Canada it was $4,380. Of the registered engineers who responded, 72 per cent were paid less than $9,000 per year for managing a water utility; the median salary of registered engineers in the United States in 1958 was $10,000. A comparison with their counterparts in gas and electric utilities shows that water utility managers receive consistently lower salaries.

### Qualifications

Recognizing the problems of inadequate plants and tremendous future growth which face the water utility manager, the committee offered four recommendations for qualifications:

1. All water utility managers should have at least a high-school education.
2. Any water utility serving a population of 5,000 or more should have a full-time manager.
3. A utility serving 10,000 or more people should have a full-time graduate engineer, preferably a registered professional engineer.
4. A utility serving a population of 25,000 or more should have a college graduate (or equivalent) as its manager.

These appear to be fundamental requirements, but the question before the industry is how to meet them with a low-wage policy that simply cannot attract qualified people in a competitive labor market.

To discuss at length managerial qualifications in this article is to put the cart before the horse. Everyone recognizes the increasingly complex and technical nature of the water utility manager's job. The committee report listed administrative responsibilities including accounting, budget preparation, purchasing, personnel, planning, engineering, construction, and public relations.

## Need in Small Utilities

Larger water utilities have, with few exceptions, competent managers who, although underpaid in most instances, have the educational background, the training from experience, the technical ability, the vision, the qualities of leadership, and the administrative ability required by the job. The real challenge to the industry is the small utility serving less than 25,000 people. Managers of such utilities are paid median salaries ranging from about $5,000 for the towns of 25,000 people to less than $3,000 for the smaller towns.

In Colorado, 826,000 people live in the eight cities with populations greater than 25,000; 367,000 reside in the 238 towns with 25,000 people or less. Almost 33 per cent of all Coloradans are, therefore, living in towns that, because of low salaries, find it very difficult or impossible to provide adequacy in water utility management. These are the managers who generally lack the educational background and other qualities needed in their vital jobs. These are the managers who do not attend AWWA section meetings or schools. These are the managers for whom the guidance and leadership recommended by the committee is most required.

Until the familiar pattern of cheap water and low salaries has been supplanted by one of realistic water rates that will make adequate plants and competitive salary scales possible, the preparation of job descriptions for and qualifications of water utility managers is, the author fears, rather academic for smaller towns and cities.

## References

1. THOMPSON, EDWARD T. The Worst Public Works Problem. *Fortune* (Dec. 1958).
2. COMMITTEE REPORT. Survey on Compensation of Water Utility Managers, 1957. *Jour. AWWA*, 51:1437 (Dec. 1959).

# Consumer Service—*Mirko D. Lubratovich and Earl H. Ruble*

*A paper presented by Mirko D. Lubratovich, Dir. of Public Utilities, and Earl H. Ruble, Cons. Engr., both of Duluth, Minn.*

The paramount features of water utility operation, so far as the customer is concerned, are quantity of water, quality of water, and dependability of the supply at adequate pressure. In these days of well advertised water shortages in many areas of the United States, the quantity of available water is probably uppermost in the minds of most consumers. A generation or more ago, quality was considered primarily in connection with bacteriologic quality because waterborne disease had not yet been brought under control. Even today, more than 15,000 water departments in the United States are delivering water of a quality that varies from place to place.

An experienced water supply superintendent would classify many public water supplies as having good quality and others as having poor quality. He would classify some as adequate in quantity and some as inadequate. He would classify some utilities as satisfactory for pressure and dependability and some as unsatisfactory. His experience would provide the primary background for his judgment. Two superintendents with widely different backgrounds would not agree in all their evaluations.

## Need for Quality Standard

A quality standard is needed as a reference against which water supplies can be measured and as a goal for individual water supply improvement. With a quality standard as a yardstick, two superintendents would be able to agree as to the relatively adequacy of water supplies.

This article suggests a few parameters that might be used as a starting point in developing a quality standard. The USPHS Drinking Water Standards [1] define a safe water, but not necessarily a good-quality water. A water with a color of 20 ppm, turbidity of 10 ppm, an iron content of 0.3 ppm, chlorides amounting to 250 ppm, and total solids of 1,000 ppm could hardly be classed as good-quality water, but such water would meet the USPHS standards.

## Good-Quality Water

The problem of defining good-quality water has been discussed by Bean.[2] He has suggested these topics for study:

1. Standards on toxic materials might be left out of a professional standard, or might comply with USPHS standards.

2. Professional standards should deal with factors not particularly associated with health implications.

3. How should detergents be handled?

4. How should pesticides be handled?

5. Should USPHS bacteriologic standards be altered?

6. What is a workable odor standard?

7. What about viruses and chlorine residuals?

8. How should corrosion and scale control be evaluated?

**Suggested Standard**

A quality standard can be established only after many points of view have been expressed and evaluated. A starting point should be established, however, as a base from which to proceed. The following tabulation is suggested in order to create a point of origin. It represents a carefully considered point of view, but it is only a viewpoint drawn from experience in northern latitudes. The composite opinion of the many who participate in creating an eventual standard is the important consideration.

With the foregoing explanation, the following quality standards are suggested as a basis for discussion:

1. Temperature of 50°F or lower, although this is difficult to influence
2. Turbidity not exceeding 3 ppm
3. Color not exceeding 5 ppm
4. Iron not exceeding a total of 0.10 ppm
5. Manganese not exceeding a total of 0.50 ppm
6. Total solids not exceeding 300 ppm
7. Taste standards on an absolute scale are impossible. A relative standard is suggested, however. Everyone in the water supply field is familiar with the expression that someone's well has "the best tasting water in the world." Fundamentally, expressions of good taste in water mean that the observer does not detect any flavor of salty, sweet, sour, or bitter character; that there is no taste response similar to the hotness of pepper or the coldness of mint; and that there is no medicinal, fishy, weedy, or musty character to the flavor. It is recommended that a statistically random and representative selection of consumers be made for a taste test. If 75 per cent rate the water as good or excellent using the above mentioned general criteria, the water would be regarded as a quality water so far as taste is concerned
8. Odor not exceeding a threshold value of 0 or 1
9. Nitrate nitrogen not exceeding 1.0 ppm
10. Detergents (ABS) not exceeding 0.05 ppm
11. pH is necessary for stability from the viewpoint of corrosion and scale control. High-pH waters sometimes do not taste good, but it is believed the taste standard would cover this characteristic
12. Adequacy and dependability may be provided by having storage equal to 2 days maximum demand. It is suggested that either dual pumping facilities and a source that has no record of failure as to quantity or an available secondary source be available
13. Residual chlorine at the consumer's tap of not less than 0.40 ppm, if chlorine is used for bactericidal purposes
14. Coliform bacteria count may be considered low enough if, of all standard 100-ml portions examined per month, not more than 1 per cent show the presence of coliform.

In certain respects, the foregoing suggested standards prescribe more stringent requirements than USPHS standards. Baylis [3] has stated that in Chicago, standards have been set that are in some respects much more rigid than USPHS standards. The trend in this direction will, in all likelihood, increase as the public learns that water quality can be upgraded by the producer as any other food product can.

Several important elements have not been mentioned so far. Most of the

elements listed below are not particularly detectable by the consumer. USPHS standards are recommended for compliance in a quality standard as well as a safe water standard for these characteristics: (1) fluorides, (2) cyanides, (3) arsenic, (4) hexavalent chromium, (5) lead, (6) barium, (7) cadmium, (8) selenium, and (9) radiologic content.

### Desirable Characteristics

There are at least a hundred measurable quality characteristics that might properly be a part of a quality standard. As more is learned about water quality, the number of characteristics that may be described in a quality standard could multiply. In the authors' opinion, however, a quality standard should be limited, so far as practicable, to five basic characteristics:

1. Adequacy and dependability of supply
2. Bacteriologic safety
3. Chemical safety
4. Physical desirability—appearance (color and turbidity), taste, and odor
5. Chemical compatibility—corrosion control and scale control.

### Need for Discussion

The specific standards suggested would define a high-quality water according to the above outline of basic qualities. These suggested standards are offered only as a starting point for discussion. After a hundred or more experienced water supply engineers and administrators have expressed their opinions, a practical and realistic revision of the suggested standards might be made. After opinions and comments have been made, a review of this article might produce an outline on which can be built a quality standard acceptable to all water utilities.

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## Rates—*Henry J. Graeser*

*A paper presented by Henry J. Graeser, Supt., Water Works, Dallas, Tex.*

Water customers are becoming aware of the value of the water they use. In many localities, this awareness was a result of drought in a growing community. Although the combination of growth and drought caused temporary inconveniences, the lesson it taught water consumers may have lasting benefits. Knowing the value of water, consumers are more ready to accept a readjustment of rates on a modern business basis.

One of the water supply industry's worst problems is that of inequitable rates. When tax support and billed revenue are mixed, for example, financial confusion may prevent adequate and responsible planning. Political expediency often leads to rates that have little relationship to the utility's cost of providing service to a customer; instead, customers with little influence pay high rates and customers whose complaints will be heard in City Hall pay low rates. In cities where industry has too much investment to move away, industry is charged more than its fair share; in cities trying to

attract industry, the domestic customer makes up for artificially low inducement rates.

### Payments to General Fund

When a city water department is considered to be a money maker for the general fund rather than an operating utility, its "payment in lieu of taxes" may rob it of income necessary for reserves, planning, management, and operation. Financial planning is sacrificed to low property taxes.

Most water department managers expect to make payments to the general fund at levels and by methods comparable to those by which the privately owned utilities in the community pay taxes. But when city governing bodies exact unfair payments for political reasons, the water department managers have no appeal. The only thing they can do is to convince administrators, elected officials, and citizens that the water department is a utility, not a tax relief operation. They may use the new awareness of the value of water to support their contention.

Another way to support this point of view—and to work toward realistic rates and finances—is by calling attention to the many comparisons between water utilities and the electric and gas utilities. Water department managers should learn the techniques of business financing, but they need not let their ideas be governed by past example. The ad valorem tax, for example, has become outworn. Water department managers may find a reasonable at-cost water rate for service to be more suitable for their purposes.

### Progress in Utility Recognition

Throughout the United States, recognition of the water department as a utility is expressed in the increasing number of water boards and authorities being set up. Some communities, however, have accomplished the same result without incurring the expense of a board. In Dallas, the city charter provided that the water and sewage utilities were to be separate entities in city financing. The water and sewer departments do not pay into the city general fund except for services that the city renders the utilities. Legal services, purchasing, general administration, and finance operations are consolidated with other city functions of a similar nature, but the utility pays for these services at cost.

### Study and Planning of Rates

Adequate rates for cash operation require adequate study and planning. With poor load factors and the increased use of water, the water supply industry must allocate costs according to the way costs are incurred.

Rate study has been facilitated by metering. At the end of World War I, a flat rate for all customers was common. Now more and more communities are completely metered; few new water systems are going into service without adequate metering.

Rate studies must take many factors into consideration. The local conditions of the community—demand rate, climatic conditions, types of users, and rate of growth—all affect the price of water. Research is needed to determine how different types of customers use water and what the facilities that serve them cost. These customer types may be used to devise rate classes.

If the proper number of class rates have been devised, only three charge factors are needed: a customer charge, a demand charge, and a commodity or unit charge. The customer charge is a minimum that includes the charges

common to all customers whether they use any water or not. Such charges are for fire protection, administration, engineering, and overhead. A 6-in. main in front of a customer's house requires the same maintenance even if the customer does not use any water from it. The demand charge, if not separate,[1] may be computed either in the minimum or the unit charge. If demand is included in the unit charge, the rate can be flat to all consumers in the same class, regardless of what they use above the minimum.

Dallas uses four classes of rates: (1) the domestic consumer and the commercial consumer with air conditioning, (2) the commercial consumer without air conditioning, (3) the industrial consumer, and (4) the outlying communities that purchase water. Each of these classes represents a type of customer with more or less the same use habits. By allocating capacity costs for peak-hour and peak-day use patterns, a suitable class rate was devised.

Studies provide the basis for rate planning, the need for which is clear. Adequate planning is essential for rates that will enable the utility to finance growth from income.

## Planning for Expansion

Rates adequate for cash operation may not be sufficient to pay for expansion. An average rate that balances increased use against increased operating and capital expenses requires a plan of expansion. Privately owned utilities use a cash reserve to pay for expansion when it is needed, but few public water departments are allowed to accumulate a reserve.

Rate planning that accommodates for growth requires a knowledge of the amount of money that will be needed, over a reasonable period of time, for expected expansion. Every growing water system must have a master plan. The number of people coming into a community, the types of customers that will have to be served—industrial, commercial, or residential—must be known. The amount of money needed must be anticipated, and so must the time when it will be needed.

Without the cash reserve of a privately owned utility, the public utility, to have adequate rates, should have an accurate estimate of its future operating expenses. It should have an idea when its debt service requirements or capital charges will occur, and of the compounding effect of these expenditures. Generally, there will be high and low periods of expenditure over 10 years. Thus the utility must have an average rate creating a cash reserve for parts of the period, a constantly changing rate, or, at some time in the period of financing, a higher rate than would otherwise be necessary.

If a utility has a master plan to show when expenses will increase, it can increase rates before a deficit appears in the budget. Thus a short-term reserve can be built that will compromise between an operating reserve and a varying rate for service. This cash reserve cannot be attacked as an excessive charge for the citizens of the future, as it merely covers part of the expansion of a reasonable period. Bonds on 20- or 25-year term, although costing 40 per cent more over their term than cash, pay for the rest of the expansion and spread the cost to the future population that will use it. When the facilities are paid off and growth has ceased for a while, rates should decrease, unless the citizens accept the necessity of building a reserve for the next surge of growth.

### Adequate Rates and Public Recognition

Adequate rates based on studies, planning, and anticipation of growth can be accomplished only if the public knows the value of water and recognizes the water department as a utility with its own financing. One factor encouraging adequate rates and public recognition is the growing popularity of revenue bonds, which has prompted better protection of water income in order to satisfy the bondholders. In a recent sale of revenue bonds, the Dallas water utility sold bonds at an interest rate lower than the rates of its municipal, tax-supported bonds. This demonstrates the confidence that bondholders have in utilities operated as a business, with water rates adequate for maintenance and expansion. Bondholders are becoming more aware of the economic value of water; they are showing their confidence in utilities that are well managed and are financially sound on their own without tax support.

In order to achieve adequate rates, adequate talent and energy must be devoted to them and to the work of getting the public to recognize the value of its water utility. The public must realize that the water utility needs management, salaries, and planning equal to that of other utilities. Rates and long-range planning for the whole utility are interdependent.

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## Plant Facilities—*William R. Seeger*

*A paper presented by William R. Seeger, Gen. Mgr. & Chief Engr., Marin Munic. Water Dist., San Rafael, Calif.*

The subject of adequacy in plant facilities is too broad for one man's opinions and attitudes to be of much value to many others. For this article, therefore, the author sent questionnaires to and received responses from one Hawaii and twelve California water utilities.

The utilities surveyed varied from small rural communities to large metropolitan areas. The author believes that the opinions expressed in this survey cover the full scope of the water supply industry. One of the respondents, the Los Angeles Water Department, serves 2,514,000 people; another, the North Marin County Water District, serves 25,000 people. Some, like the East Bay Municipal Utility District, use surface water; others, like the Southern California Water Co., use ground water and surface water sources. Opinions on plant facility adequacy among the chief engineers of these utilities also varied widely.

In the questionnaire, respondents were asked to express their opinions on the meaning of *adequacy* when applied to these plant facilities: water supply, terminal storage, transmission lines, pump stations, filter plants, distribution storage, distribution lines, service connections, and pressure zones.

### Water Supply

The survey indicated that, when a utility obtains a supply from well fields with an underground basin in which wells can be constructed within 1–2

years of the demand, the daily capacity of the well system should be approximately 150 per cent of the average daily draft. In systems that are taking their water supply from rivers, the capacity should also be approximately 150 per cent of the average daily draft. In impounding reservoirs or surface storage, the capacity is largely dependent on availability of dam sites, seasonal variation in the supply, and the general climatic history of the area, as well as on the time required for construction.

Generally speaking, it was the opinion of all respondents that it is extremely difficult to define the *adequacy* of a basic water supply, as adequacy when dealing with a well supply is different from adequacy of a river supply or of an impounded storage supply. It is probably not possible to give one concrete figure on which a water utility operator could rely in designing a source. Each supply is individual and depends on many variables.

### Terminal Storage

In this article, terminal storage is the storage adjacent to the service area. The approach in determining the capacity of terminal storage was based, in most instances, on protecting against an outage in the main transmission line from the source of supply. The terminal storage would supply water to the distribution system until adequate repairs on the source were made. Here again, it was difficult to establish a single adequate storage figure, as the capacity of storage facilities largely depends on the location of storage in relation to the source of supply. The bare minimum of terminal storage, it seems, should be storage for a full 3 days, plus the fire requirements of the National Board of Fire Underwriters (NBFU), for smaller systems, and a maximum of 90 days for large metropolitan areas. Some organizations try to estimate the seriousness of a transmission line break and the length of time required to repair this damage. In this way they develop terminal storage to provide for such an outage.

It was interesting to note that in the large systems, the problem of terminal storage was felt to be quite serious. With these utilities, storage for 30–90 days was indicated.

Generally speaking, the survey indicated that in communities where the transmission facility from the source of supply was by means of long aqueducts and the number of consumers was above 250,000, terminal storage minimums for 30–90 days were thought desirable. In smaller communities, where the supply was closer to the service area and the supply lines from the water development to the terminal storage were classed as pipelines rather than as aqueducts, storage for at least 3 days in the terminal reservoirs was considered sufficient.

### Transmission Lines

Everyone knows the desirability of having transmission lines as large as possible. But with transmission lines (as distinguished from distribution lines), increasing diameters mean tremendous increases in cost; the matter of economic justification is involved. Opinion is mixed as to whether transmission lines should be designed on the basis of percentage of present flow or whether they should be designed to carry the flow anticipated in some years. When a transmission line is installed, it is usually one that will carry the anticipated demands for at least 20 years, as transmission lines, unlike distribution lines, cannot be

cross connected or netted in order to increase their capacity.

Adequacy in transmission lines depends on whether the system is gravity or pumped. The approach with a gravity system is entirely different from that with a pumped system. On a pumped transmission line, the economics of pumping plants, power, and additional friction loss as compared to the cost of the particular pipeline is involved. With a gravity system, on the other hand, only the amount of water to be taken through a particular line need be compared to pipeline cost.

The size of transmission lines is also dependent on the availability of storage for meeting peak demands. If a transmission line is to be called on to meet the peak demands, it must be large enough to handle probably 200 per cent of the average day; if storage is available in the system, the line capacity can be cut somewhat, depending on the location of the storage in the overall layout of the system.

### Pump Stations

For pump stations to be adequate to meet the demands placed on them, one of the important things to be considered is standby units in case of power outages. This can be taken care of either by gas-driven standby units or by providing additional storage above the generally recognized standard for pumped storage. Consideration should also be given for a standby pump in the case of a motor or pump failure. On low-lift pumps, the capacity should be approximately 200 per cent of the average daily draft; on high-lift pumps, the capacity should be approximately 300 per cent of the average daily draft.

The design of pumping systems ties in with the design of the storage tanks. In fact, it is not good design to handle them separately; pumping systems should be considered as both pumping plants and the storage reservoirs. A pumping plant designed to operate for 8 hr per day, in combination with a storage tank adequate to meet a 2-day demand, will usually prove adequate to meet most of the demands placed upon it.

### Filter Plants

Filter plant capacities are generally a function of the distribution system. Generally speaking, the capacity should be approximately 150 per cent of the average daily draft, providing for at least one reserve filter unit out of operation for backwashing.

### Distribution Storage

In gravity pressure zones, the capacity should be equal to 1.5 times the maximum daily demand or 3 times the gross average demand. In pump pressure zones, the capacity should be equal to 2 times the maximum daily demand or 4 times the gross average demand. The survey indicated that it would be desirable if storage for 3 days could be provided.

### Distribution Lines

It is interesting to note that as the survey touched areas where more information is known and where more specific answers can be given, there tended to be more agreement between the respondents. A great deal of recognition was given to NBFU recommendations. It was almost a unanimous opinion that if NBFU standards are met there would be adequate water for all services. The design of distribution lines must, of course, meet the fire flow requirements as well as maintain a minimum pressure drop during periods of peak flows.

One utility indicated that a standard design of a distribution system was a network of 12-in. mains on 0.5-mi spacing each way and 6-in. mains within each grid reinforced with 8-in. headers. It was generally conceded that minimum size of lines should not be below 6 in. Another criterion of line capacity is that the line should be ample to handle maximum flows (4 times the gross average over the maximum day), or 2 times the gross average day plus the fire flow, whichever is more critical.

Another utility indicated that its system is designed to provide a domestic fire flow plus a fire demand on a maximum day. Another comment indicates that a distribution line is only adequate when it can handle the present and future demands that are likely to be placed on it.

It is generally conceded that establishing a percentage of average daily output is not possible when dealing with the distribution lines, but that such things as fire flows and future expansion as well as permissible and allowable head losses must be given consideration also.

## Service Connections

The survey indicated that generally, where ¾-in. connections had been considered adequate, consideration should now be given to changing standards to at least 1-in. service lines, as more water-consuming household devices are being marketed and water sales per consumer are increasing yearly.

In determining the size of service connections, consideration should also be given to the pressure in the main. In other words, on the border of the low-pressure limit, the system should be designed so that minimum pressure drops occur in the service line; in areas with high pressure, smaller service pipes can be satisfactory.

## Pressure Zones

It is the general consensus of opinion that previously 30 psi was considered adequate, but now, because of modern living, it is desirable to increase this to probably 40–45 psi where possible. Generally speaking, pressures are maintained between 40 and 100 psi.

Customers usually complain only when pressure fluctuates seriously. A change in pressure from 80 to 40 psi will cause more complaints than a pressure of 40 or 45 psi if it remains steady and constant.

On sloping lots, there can be adequate pressure at the low side of the lot and inadequate pressure at the high side. This problem has been solved in some utilities by setting regulations requiring that service will be granted only if there is a minimum available pressure at the high side of the lot.

## Conclusions

Each water supply man has his own opinion on adequacy in his own system, but there appeared throughout the survey three factors that determine attitudes on adequacy:

1. *Type of System.* Adequacy is dependent on the type of system and on the source of supply. For example, adequate storage for a system located a long distance from its supply is different from adequate storage for a system using well supplies right next to the terminal storage.

2. *Economic Situation.* Everyone would like to have the best installations, but this costs money. Economic conditions will largely determine the

extent to which a system can be enlarged and improved.

3. *Future Adequacy.* Another variable that must be specified in order to receive uniform information on adequacy is the length of time for which a system is expected to do the job. Is a system adequate if it provides good service today, or must the same system also be capable of doing so next year, 5 years hence, or 10 years hence? In a given system, each part of the plant facilities will have its own duration of adequacy. This duration would apply to this part in any system regardless of size and type.

First a determination should be made of what factors and considerations must be taken into account in designing for an adequate system. Then durations of adequacy should be specified.

To be adequate, a system should provide noninterruptable service. This would be the highest level of adequacy. Then, depending on economic conditions, it may be defined that a system with minor interruptions would be on a secondary level of adequacy.

The author believes that it will be possible only to set up general guides rather than to specify percentages of annual, monthly, daily, or hourly flow. This type of calculation will come after the basic considerations are taken into account.

Adequacy for a source development would not be the same as distribution adequacy. To be adequate, a system should have source developments available that will be adequate for 20 years from this time when a new development project is started. When the population has grown until the supply has only a 5-year adequacy, another development project should be started. This 5-year head start is made on the assumption that it would take 5 years from the time of planning a project until water is made available. With storage, however, it only takes a matter of months to provide additional tanks. The same goes for pumping plants, so a system could have a high rating with storage facilities adequate for 10 years and a storage system holding enough water for the demand of several days.

It is the author's opinion that although it might be possible to set up ground rules for adequacy that would apply to any system regardless of size and regardless of type of system, they can only be in general terms.

**Acknowledgments**

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## Accounting Practices—*Ralph L. Swingley*

*A paper presented by Ralph L. Swingley, Vice-Pres. & Controller, Indianapolis Water Co., Indianapolis, Ind.*

Every utility wants adequate accounting practices. Anything less than up-to-date, comprehensive, and efficient practices are inadequate, and no water utility can afford practices or systems that are inadequate.

Good accounting practices are quite well defined. A new, modern uniform system of accounts has been adopted by NARUC.[1] Many states have adopted this system, and have it in use today. Plans are under way to update the *Manual of Water Works Accounting* that was prepared jointly by AWWA and the Municipal Finance Officers Association and published in 1938. Good booklets and articles that give sound information on almost any phase of accounting are available. There are many fine mechanical systems with a demonstrated record of successful operation.

Everyone has access to recommended methods, systems, and practices; he should be willing to accept these practices and use them at his utility. Utility managers need the vision and drive to bring their practices to the level they know they should have.

Each water utility manager should consider and review all phases of his accounting operations and try to measure it against what he ought to be doing. These questions might stimulate such a review:

Is customer billing and accounting properly mechanized? Is it over mechanized? Does the utility have too much mechanical equipment? Are small jobs that shouldn't be done by the equipment mechanized? Is work under continuous study, and after careful analysis is more of it being mechanized?

Does the utility have a complete continuing property record? Is it backed up by a sound work order system? Is material being controlled? Does the utility have a sound record of receipts, disbursements, and quantities on hand? Are statistics adequate? Is the amount of pumpage lost known? Does the utility have an adequate analysis of costs? Are cost analyses used as a management tool?

How can a water utility's accounting practices be examined? There are so many facets to good accounting for a utility that the only sound way is to group them in these categories: (1) customer billing, collecting and accounting; (2) general accounting; and (3) general records and statistics (usually maintained by the accounting department).

A rating scale for water utilities has been prepared[2] for the areas of general accounting; customer billing, collecting and accounting; and general records and statistics. This rating scale breaks each area down into a series of parts, and gives the manager an opportunity to rate his own utility in these fields. As he uses this scale, he judges whether he has an accounting system that completely meets requirements, and if not, how far his system falls below that which he ought to have.

Use of this rating scale is the best way the author knows for a manager to check the adequacy and effectiveness

of his accounting practices. The rating scale will raise questions that will cause the manager to consider areas in which he can do a better job. If he has questions and does something about them, his accounting practices will improve in their adequacy.


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## —Engineering and Engineering Records—*E. Jerry Allen*—

*A paper presented by E. Jerry Allen, Asst. Supt., Water Dept., Seattle, Wash.*

All water utilities require technical or engineering services. Many larger utilities are regularly staffed with a variety of specialized engineers; others depend primarily on the services of consulting engineers. Besides these two distinct groups, there are utilities that, for any of a variety of reasons, may lack adequate technical or engineering services and proper engineering records.

The kinds of engineering services [1] required by water utilities are: (1) preliminary investigation and reports; (2) preparation of comprehensive plans or programs; (3) feasibility studies and reports, including advice on financing; (4) preparation of plans, specifications, cost estimates, and contract documents; (5) rate studies; (6) supervision of construction; (7) studies of operating procedures; (8) appraisals; (9) expert testimony; and (10) special consultations for problems of a complex character. The proper accomplishment of any of these services will often draw on the talents of several specialized engineers, as well as require accurate information, details, and records from the utility.

### Engineering

Adequate engineering does not stop with plans and specifications. The best of plans and specifications will not guarantee a satisfactory job. Successful construction requires capable, experienced engineering supervision. During construction, modifications and field decisions may normally be expected to occur. Such changes and decisions may be expected to be no better than the engineering judgment and experience of the supervisor. Application of sound, capable engineering ability, coupled with judgment gained from experience, will pay dividends in forestalling litigation between contractor and principal.

Few utilities have the means to maintain a complete staff of engineers fully capable of performing the variety and quality of engineering services required. It is just as reasonable to retain capable engineering services for engineering work as it is to consult a capable doctor when medical or health advice is needed. Practicing engineers specializing in the various water utility fields with a background of experience as evidence of their ability should be employed for major work or difficult problems.

Engineers of integrity, with specialized education, experience, technical knowledge, sound judgment, and a background of successful practice, are available to any utility. Probably the

best recommendation of an engineer is continuous service to clients and repeat performance.[2]

Proper selection of engineering and legal counsel should be given sufficient thought. There are specialists in all professions. Utilities faced with specialized engineering requirements should employ engineers with the training and experience background qualifying them to handle such problems adequately. Engineers recommended by employers of engineers or by engineering societies may be selected for interview to determine the one with the most appropriate experience background. After a utility manager selects the best qualified engineer, he should negotiate for the desired services with a full and complete mutual understanding of the nature and extent of engineering services. A check on fees that the engineer will charge may readily be made through the sources of recommendation.[3]

The cost of engineering services should not be the sole consideration in selecting professional advice or assistance. Professional services by engineers with experience and professional reputation can often save many times the amount paid for such services. Competent engineering usually results in lower costs through better bids, better inspection, better construction, and better financing.

Management is responsible for timely and adequate engineering. Managers must be alert to the requirements of their utilities for customer service both present and future. Then they must take the necessary steps to assure that proper water supply and system facilities are available when needed.[4] Proper planning by management gives consideration to requirements far into the future. That a USPHS survey[5] shows major deficiencies in supply, transmission, pumping, treatment, storage, and distribution is evidence of inadequate planning.

Faust[6] points out that although 97.3 per cent of the nation's water utilities serve communities with less than 25,000 people, the recorded deficiencies indicate that some of the larger communities may also lack good engineers. The problem of adequate engineering is not necessarily a function of utility size.

Service area growth and expansion must be anticipated, and so must adequate facilities to meet that growth and increased consumption. Continuity of water service may require planning for additional or supplemental sources. Many factors indicate the desirability of safe, well developed dual supplies.

## Engineering Records

Engineering records are essential for studies, proper planning, and operation. Maintaining the continuity of practically any water utility records ranging from source of supply through physical plant to consumption is of inestimable value in planning. It provides background data for necessary engineering.

The increasing scarcity of available water sources that may be developed economically increases the value of existing water rights. The importance of records for use in courts of law to protect water rights indicates that the source of supply should be identified and recorded accurately as to location, quantity of diversion or withdrawal, methods of measurement, water quality at the source, first dates of use of source, permits, leases, agreements, and property ownership. Permits, leases, agreements, and deeds

should be properly recorded in accord with state laws. Specific dates for all such records are important.

No water utility is too large or too small to maintain comprehensive map records of all utility installations and service areas. All maps should be accurately and properly scaled to show the information recorded. Map records should consist of contour maps, overall system maps, sectionalized system maps, service areas, and utility property ownership maps.

Distribution system maps should include and record water mains, valves, hydrants, and some individual services. The prime consideration is that all features shown should be properly identified as to size and properly located with relation to fixed "ties" such as section corners, recorded monuments, or recorded property lines.

The utility installations shown should be dated and identified with reference to work orders, jobs, ordinances, or other authorizing documents or plans that provide detail. Records of flow, pumping, static pressures, water treated, water delivered, leakage loss, and valve operations, all showing dates, are of great value for planning as well as for proper operating procedures.

Careful planning of distribution system records is necessary to determine the forms to be used, the amount of information to be recorded, and the procedures that will assure a continuity of record.[7]

It is expected that treatment plant operating records will be maintained. Aside from operating and treatment procedures, however, specific records should be maintained showing physical plant layout. Such plans and records should always be made and dated whenever any physical change is made in a plant. Records of the operating results obtained after such changes should also be made.

One of the most useful records is that of costs and revenues. Cost accounting for water is directly related to the feasibility of required improvements, operating procedures, and revenues available or required to finance plant changes or expansion. The engineer has a direct and vital interest in financial accounting, as it is a part of every water utility engineering function. The correlation of cost records with construction is vital for a properly programed improvement. Other aspects of engineering activity that require proper accounting records are valuations and appraisals, cost analysis, reserve requirements, depreciation rate studies, formulation of rate structures, and forecasting of revenue and expense. Such specialized engineering functions can well be performed by capable consulting engineers who fully understand their role in determining and interpreting data relating to financing and revenues.[8] The correlation of accounting records and engineering reports is necessary for management to determine the feasibility of proposed programs.[9]

Engineering reports should be retained with all other permanent engineering records in a safe, well protected location where danger of fire and deterioration is kept to a minimum. Not only should duplicate records be kept of all design plans, reports, and specifications, but working copies should always be duplicates. The original records should be maintained for reference only. Many utilities find there is safety and economy in microfilming such records. Some utilities provide a factor of safety by

filing duplicate records some distance from the originals.

Although engineering reports are of great value for future reference, and are the very foundation for conception and design of facilities, truly effective reports are based on background engineering records of a utility. The preliminary study, the necessary data, and the concluding solution require a true engineering analysis to state properly the purpose and to present the relevant facts and requirements. The summary of findings and the conclusions and recommendations giving in detail the benefits to be obtained, the cost, and possibly the means of financing cannot be made without those facts.

Preparation of plans, specifications, and realistic cost estimates to accomplish the purpose desired must be based on sound, adequate engineering reports with full consideration given to comprehensive plans for development (a major engineering study), feasibility reports, operating costs, and, above all, special consultations and advice for problems of a complex or unusual character.

## Conclusion

New water supply demands from population increase and increase in per capita consumption require adequate planning and engineering.[10] Public water utility requirements are expected to soar from 16.3 bgd in 1955 to 32 bgd in 1980, an increase of practically 100 per cent in 25 years.[11] People in the water supply field must also accept their responsibility for continuity of water service during emergency situations, whether such emergencies are caused by nature, are man-made accidents, or are military catastrophes. The willingness and ability to do their jobs through proper planning and preparation will in large measure determine whether water supply people will control the destinies of their utilities. Cooperation between management and qualified engineers will set the stage for sound planning, adequate engineering, suitable rate structures, and appropriate financing.

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## Planning—*James W. MacLaren*

*A paper presented by James W. MacLaren, Partner, James F. MacLaren Assocs., Toronto, Ont.*

The supply and distribution of water of an acceptable standard in adequate quantity and at a sufficient pressure have been considered by many municipal utilities as goals almost impracticable to attain. In comparison with the accomplishments of industry, this situation is completely inadequate.

Such conditions have been intensified with the explosive development of suburbia in many communities since World War II. Water utilities have found it most difficult to maintain adequate service to meet the increasing demand. It was reported in 1953 that over 1,000 utilities in Canada and the United States had to restrict the supply and distribution of water because of inadequate planning, a direct result of extensive suburban growth.

In years past, the distribution system of major cities usually served as the core from which to extend the water distribution system. With extensive perimeter growth, however, the core was weakened; it required substantial reinforcement to sustain the utility's service. Soon water in these newer areas had to be carried 2–3 times as far to serve the same number of people as in the older city. This presented a serious probem to the utility, especially in increasing costs per customer. The problem of an adequate rate structure to sustain water utility expansion has been basic throughout the industry, and is aggravated by suburban developments.

Another obstacle to the development of a properly planned water system is the limiting effect of municipal boundaries. Although arrangements for the sale of water can be made between one community and another, in many places no proper plan can be developed with regard to adequate trunk main service between adjacent communities. This is generally owing to the political atmosphere that often beclouds and restricts engineering judgment in municipal affairs.

The foregoing has suggested a rather gloomy outlook in the water industry for modern and adequate planning. Fortunately, however, many factors favor improvement, modern planning methods, and analyzer and computer techniques.

Area planning for the utility can be considered the most important and valuable aid in establishing and maintaining an adequate service within a specific planning period. The creation of modern planning commissions or planning boards within the past 20 years in North America has been of considerable benefit to the planned development of all municipal services.

Without a major plan for water supply improvement as a part of a master plan of community development, the utility has no help in assessing the advisability of major land development schemes when these schemes are placed before it for comment and approval. The scheme is likely to gain approval, and the utility later finds that untimely and unwarranted extensions are required to supply service to it.

It is no longer necessary for major inadequacies to exist in water utility systems. If a modern water development plan is prepared and recommended with the approval of the local planning commission, especially if this plan is presented after a restriction of supply resulting from inadequate facilities, public opinion is generally sufficient to force its acceptance, including the necessary rate increases. If the plan encompasses not only the construction necessary to overcome present inadequacies but also incorporates a plan of future development, a foundation is established for the planned construction of work necessary to meet the increasing water requirements of a growing municipality. Many utilities have successfully followed such a scheme in recent years.

This article indicates the basic facts that should be incorporated in such a plan to establish and maintain adequacy over 20–25 years.

### Forecasts of Water Consumption

Municipal and area planning commissions have been of invaluable assistance to the water supply engineer in the determination of future water requirements. They maintain studies of present land use, population statistics by census tracts, building permit records, established zoning principles indicating immediate areas of anticipated growth, and population forecasts for 20–30 years in the future. Even if the utility does not agree with their findings and proposals, it must be admitted that the planning authority has been established as a technical body operating at the behest of local government to provide a realistic development plan for improving future living conditions in the area. Unless major objections to the policy are clearly in order, therefore, the utility should recognize this municipal service and use its basic information in establishing the development plan.

From existing land use plans and studies as well as from aerial photographs, residential, commercial and industrial establishment of various densities and types can be located. Statistics on water consumption by meter districts and major commercial and industrial consumers can then be utilized to establish unit acreage consumption rates for water in areas of varying type and density. Such unit rates, when applied to the existing land use figures, should provide a total water consumption figure equal to the current average consumption. The latter figure provides the check for the exercise. If reasonable similarity cannot be established, the land use figures and unit consumption figures must be reviewed until the gross figures are consistent.

It is then practicable to forecast the areas of future growth according to zoning bylaws, estimating the degree of saturation within the planning period. Existing areas must be reviewed in similar fashion to determine the possibility of redevelopment and its effects on density and type of land use. Blighted areas of the old city may be converted to residential or commercial developments. Population forecasts established by the foregoing procedures must, however, when added up, concur with the actual forecast established for the whole area. If not, reinvestigation must be carried out to correct the error.

Once the plan of future development is confirmed with the agreement of the planning commission, unit water consumption figures can then be applied to areas of various density and type to establish the forecast of average demand for the end of the planning pe-

riod. These unit figures must be derived from current applicable consumption rates, but with allowances for an increasing use of water. Errors may creep into these unit figures if full cognizance and study are not given to the value of existing unit figures. Industrial and commercial unit acreage consumption rates must be determined with care. Private concerns often establish themselves on enough land to double the size of their plants in the future. Such extensions would double existing unit consumption rates. Redevelopment with allowance for open land in new housing schemes generally does not materially affect the original unit consumption rates, but changing land use may do so radically.

The increasing use of water by people in all types of development at rates of 0.5–2.5 gpcd per year, determined through forecasting past increases, must also be taken into account in any future unit rates. Furthermore, lawn-watering restrictions, areas with septic tank use, areas of low water pressures, and the probability of continuing use of water from private sources requires evaluation.

With these estimates and forecasts, a general plan of future water use in the municipality can be developed and point loads can be assigned throughout the service area. The point load assignments are based on 1,000-acre blocks for larger utilities and 100-acre blocks or less for smaller systems. This gives a forecast of average water requirements for the planning period, and the forecast is actually plotted with relation to the growth pattern forecasts to establish distribution requirements.

The estimates of usage discussed so far have been of average demand. To use this forecast plan for distribution planning, an assessment of maximum day and maximum hour requirements for water must be made. The overall municipal figure will be based on projecting past patterns into the future. Ratios of maximum to average use will become higher because service will be improved: lawn-watering and other restrictions will be lifted. Area types will, however, vary in peak demand requirements and peak demand periods. Industrial and residential peaks are generally not coincident. The distribution forecast plan must be modified for peak hour analysis, checking for both industrial and residential peak requirements.

A further requirement that must be considered in laying out the distribution loads is the allowance for fire fighting. In smaller utilities this must generally be added to the peak hour demand. In larger communities, peak hour requirements at reasonable delivery pressures are generally satisfactory for meeting fire requirements. The maintenance of 30 psi of pressure in the lateral main during the peak hour demand with lawn watering unrestricted and fire allowance excluded appears satisfactory for larger systems. With smaller communities of 50,000 people or less, a lateral main pressure of 20 psi probably should suffice with fire allowance included. Recent statements by NBFU indicate agreement with this principle.

It is unlikely that requirements can reasonably be forecast further ahead than 20 years. With the above procedures, however, a sound basis has been established for the distribution requirements of the municipality and the supply requirements of the system for a significant period in the future.

**Development of Future Supply**

Before a distribution network can be properly designed, it is necessary to determine if the existing supply

source and its treatment units, if any, will remain satisfactory over the planning period. It is necessary to know if the distribution system will continue to receive its water from the same general direction and in the same general manner. Supply presents a problem of longer range than does distribution. Any planning for its expansion under normal conditions should be on the basis of 25 years or more.

The source of supply must be examined to determine the extent to which its existing capacity will satisfy future demands. If insufficient for the planning period, plans should be made to expand it. Alternative sources with treatment and pumping must be investigated for their suitability. Development dates for the alternative sources considered satisfactory should be established according to the future water demand forecast. Capacity of the supply with respect to the average day of the maximum month and the maximum day should be investigated. Where the supply is right next to the distribution system, the capacity should be based on maximum day or even maximum hour. Remote supplies involving transmission lines will require economic studies to determine pipe size and terminal reservoir capacity, based on the demand for the maximum day, the average day of the maximum month, or even the average day of the maximum 3 months.

Examination of existing or alternative sources of supply should consider current and anticipated pollutional effects. Considerations of future pollution should include the study of new and more complex industrial wastes, lower dilutional ratios, greater algae concentrations, radioactive wastes, detergent concentrations, and other taste- and odor-producing substances. Such examination may reveal that new and more expensive levels of treatment may be required, intakes must be relocated, or operating levels in well fields altered.

A utility may determine on investigation that because of increased requirements or water quality, a supply should be abandoned and a complete new development commenced. Under such circumstances the method and location of supplying the distribution system must be reviewed with care. If the existing source must be supplemented from another source because of its inadequacy for future requirements, consideration must be given to the method of combining both supplies for ease of system operation. The second source has the added advantage of providing diversity of supply for the general public safety. Consideration must be given the initial capacity of the new supply. The capacity may have to be great enough to permit the existing supply to be removed from service right after the new supply begins to operate. This would permit rebuilding or remodeling the older supply for more efficient operation.

Investigations should be made of new treatment methods, including the applicability of and economies effected by high-rate filtration to meet peak loads, centralized treatment if more than one source is involved, improved taste and odor procedures, economic studies of the most suitable method of power development, and improved intake location to collect water at a point where treatment and icing problems may be reduced to a minimum.

Whatever expansion of supply is necessary to meet the planning-period requirements, the supply must also be capable of further development or integration to assure adequacy of supply

throughout the foreseeable future. Distribution might vary, and its development has to be reviewed from time to time, but estimates of supply requirements must never be lower than a conservative level. Economy must never be the sole basis of evaluation of supply development plans. No municipality can hope to develop on a sound basis if it cannot assure itself of a water supply in sufficient quality and quantity to meet its most ambitious requirements.

## Distribution System Development Plans

The distribution requirements of the system for the planning period have been determined for average and maximum conditions. The locations at which future supplies of water will be made available to the distribution system have been established. It now remains to size and locate the mains, repumping stations, reservoirs, and elevated storage tanks to permit the adequate development of the distribution system through the planning period.

These facilities should be sized under the flow and minimum pressure conditions previously listed, assuming an unrestricted use of water. Lawn-watering restrictions should not be considered in the planned development of a distribution system. If rates are adequate and fair, a utility is in business to sell water, not to restrict its use. Besides, restricted use under peak hour conditions today represents restricted use under average conditions 5 years hence.

Before the adequacy of the existing distribution system to fulfill future requirements can be assessed, the friction factor of the system's major mains must be determined, and an estimate made of these factors through the planning period. Using the existing system with the *C* factors established, trial distribution systems to provide water in sufficient quantity and pressure to meet the requirements of the forecast period can then be planned.

These trial systems should be planned according to the size and topography of the municipality. In the smaller system under flat topographic conditions, the distribution system of trunk mains would probably involve elevated storage in at least one location. In the larger system under similar ground profile conditions, it is improbable that elevated storage would be suitable. Ground reservoirs and attendant pumping facilities, including standby facilities, could meet the system demand. Such systems as indicated above would probably require higher main velocities than would be necessary in a system where topographic relief was such that the large volumes of ground storage could be located at an elevated place in the system. With this kind of system, standby pumping facilities might not be important. Mains could be sized to provide for flow in two directions during peak load hours. The principal requirements of the trunk main system might be the filling of elevated reservoirs during the minimum hours of the maximum day in order to meet the peak hours of the day to come.

The decision to include repumping stations as an integral part of the future distribution network depends on local system conditions. When repumping is employed, main feeders on both the suction and discharge sides of the station must be adequately sized so that pressure fluctuations from friction loss at varying flow rates will

remain within reasonable limits. Generally, this can be done by assuming that at the peak main velocity, friction loss does not exceed 3 ft in 1,000 ft of main. This is normally the maximum loss consistent with economical operation.

In the design of systems including repumping facilities, unfortunately, there is a tendency to overload the suction mains in the established core of the system. This reduces system pressures below satisfactory levels during peak demand periods. Similarly, there is a possibility of undersizing the discharge mains for economy. This creates abnormal station backpressures and pipeline losses during peak load periods.

Repumping facilities are a necessity, however, in areas where there is much variation in ground level, and pressure districts must be established to maintain distribution pressures within reasonable limits. In such systems, surface reservoirs floating on the district system stabilize system pressures and reduce main velocities through two-way flow under peak demand conditions. For relatively flat areas, repumping as an integral part of the distribution system has been used to overcome friction loss in mains and to minimize major main construction. This has often been the case in systems extending long distances from the originating pumping station, where repumping may be required in the more remote sections of the system to prevent distribution pressure from dropping below an acceptable level. Too often this solution serves only as an interim measure. When development grows past the booster station location, the booster station soon becomes useless to the system, and major mains must be extended to sustain pressure. This temporary solution also involves system isolation on a wide scale, and reliability of service is lost.

In any case, it is wise to establish two or three types of trial system to meet the requirements for distribution within the planning period. Each system should then be analyzed to determine main sizes and pumping station and reservoir capacities. Systems should be analyzed on the assumption that major mains are out of service and electric power has failed but reservoir and standby pumping equipment are operating. This analysis will determine the reliability of the systems under emergency conditions.

Analyses of the assumed systems can be carried out rapidly and accurately with the electronic fluid network analyzer or a digital computer. The network analyzer has proven to be phenomenally accurate. It provides a flexible and relatively easy method of evaluating the future adequacy of a distribution system, including the sizing of mains and, to some degree, it assists in determining the timing for their construction. A digital computer can also be used to great advantage. It requires less simplification than does the network analyzer, which is, of course, limited in the number of mains that can be simulated. The computer, however, provides only pressures and flows for one flow condition. A major alteration must be made if flow conditions are to be revaluated following the change in the size of a main. Either system is applicable, however, and the accuracy of computing methods and necessary assumptions are generally checked by simulating the last peak load conditions on record before investigations of the future systems began. Several assumed systems, located and sized in this fashion to sustain minimum pressures under peak demand con-

ditions, can be evaluated economically and practically to determine the optimum system for future requirements.

Whatever scheme is adopted, it should be conservatively sized so that any normal change in the development plans of the community will not destroy the usefulness of the proposed system. In locating mains and other works required in the water development plan, it is desirable to take cognizance of the future road development plans of the community. This insures that mains are established in the optimum location and will interfere as little as feasible with road and other utility construction programs. The trunk main, reservoir, and pumping station construction program must be laid out in stages over the planning period, anticipating service for the areas of immediately predicted growth in the initial years, and for the more remote areas in the later years. Five-year capital works plans over the planning period are suggested as a basis for establishing approximately equal capital spending periods in the program.

## Current Planning and New Developments

A long-term plan for establishing and maintaining adequacy in water service has been discussed above. With such a plan, a utility is able to make an assessment of its capital spending in the years ahead. It can then determine if actual revenues from existing rate schedules will be sufficient to meet the financing requirements of the capital works program, assuming future increases in consumption. If such examination shows a lack in reserve funds to meet increased capital debt, rate increases can be planned for future dates to keep pace with optimum system development. This long-range plan of development should not, of course, be followed blindly. It must be reviewed at regular intervals to determine if it is still adequate for the development of the community as the growth occurs. Alterations should be made in the program as actual development dictates.

Even with a long-range plan, new developments and day-to-day operation of the utility disclose matters that only current planning can utilize to improve the regular adequacy, service, and economy of the utility. Automatic and supervisory control of pumping stations and reservoirs, where several are involved in a system, offers a substantial potential saving and an opportunity to gain better system control and response. As yet these systems have not been widely accepted by the major water utilities, but further expansion may provide an excellent opportunity to assess the operation of stations under such control. A related possibility is the use of a data-processing system on the operating analysis of complicated systems to permit forecasting of day-to-day operation.

Current planning involves obtaining properties for the building of works contemplated in the long-range program. Where reservoirs, pumping stations, and treatment plants will be built in the future, properties should be set aside as soon as possible. Money should be provided for their purchase to prevent excessive expenditures later.

Observation of water that is unaccounted for and of system leakage control, if regularly carried out under current planning, can result in considerable economy in utility operation. Observation of *C* factor status in major mains discloses if capacity is deteriorating and if the design of fu-

ture mains should take any such changes into consideration. Regular checks of the distribution network using analyzer or computer equipment can usually assist in these observations as well as revealing closed valves and other abnormal functions. New materials, the use of customer metering, valve standardization, and accuracy of meters are all matters involving current planning. The rate assessment policy towards new water-conserving devices is important. Air conditioning and its water requirements are excellent examples. Should unconserved units be permitted if appropriate water rates are charged, or should recirculating units be required in any case?

New developments in social life affect water utilities. Commercial television, for example, has created half hour peaks through the evening and a major peak after the late show. Evidence indicates that this may be causing distress to utilities employing closed distribution systems. Current planning should investigate such matters.

## Conclusion

A general review of an adequate development plan for the modern water utility has been presented. To operate from year to year without a specific plan of future requirements is to court trouble. A 20–25 year plan of development based on 5-year programs assumes that adequate facilities are available at any time, not only to meet today's requirements but those anticipated 5 years hence. If such facilities are not established, it may well be that when the system suddenly shows its weaknesses through a sustained hot-weather period, the financial aspects of a rebuilding program will prove catastrophic to the municipality, and restricted operation must be enforced for several years until the weaknesses can be corrected.

To establish the necessity of an adequate development plan, the energies of the utility's officers must be devoted to a substantial public relations program so that all responsible citizens are aware that only by planning ahead can the utility provide adequate service on a sound financial basis.

The warning of technical experts from all sides is sufficient indication of the necessity for adequate planning. Rapidly increasing demands deplete available supplies while new industrial wastes threaten the sufficiency of existing water treatment methods. Under such circumstances adequate planning on both a long-range and a current basis is a necessity for the proper protection of today's water utilities.

# Public Relations—*Johnie E. Williams*

*A paper presented by Johnie E. Williams, Water Supt., San Angelo, Tex.*

Water utility managers and personnel are becoming increasingly aware of the value of maintaining friendly relations with their customers and their community. This awareness has been manifested by the numerous articles on public relations that have appeared in trade journals, and by the number of times that the subject has been included in local, state, and national programs. Most of the published articles describe how a public

relations program operates in the community in which the author resides. Few of the authors have attempted to outline a public relations program that would be adequate for any water utility, large or small.

What is public relations in a water utility? It is the relationship that exists between the utility and the people who do business with it. No utility or utility management can choose whether or not it will have public relations; it can only decide how good or bad it wants its public relations to be.

Adequacy in water utility operations has been defined. Adequacy in water utility public relations is achieved when the public knows and understands what the utility is doing and is planning to do. Public relations is adequate when the people are confident that the utility's program is sound in engineering, economically feasible, and is the best program for the community.

Public relations is the mirror that reflects the utility's personality and its traits. The adequacy of these traits determines the overall adequacy of the water utility's public relations. These traits include, but are not limited to, facilities; an informed public; trained and dedicated personnel; sound and definite policies; attractive properties, equipment, and personnel; and friendly customer relations.

**Adequate Facilities**

The primary function of a water utility is to deliver to the customers an adequate quantity of good-quality water. Customers who receive these services are usually friendly toward the utility. Customers who are convinced that they are not receiving the service that they are entitled to receive will not remain sympathetic toward a water utility. Adequate service is essential to adequate public relations.

**Informed Public**

Keeping the public informed of activities of the water utility should be the daily concern of every utility manager. Many managers are not fully aware of the interest that the public has in the utility's operation. When water users are told how their utility operates and are kept advised as to what is taking place, public interest in that utility will always be active. Telling the water utility story is essential to adequacy in public relations.

In many large utilities the duty of telling the story is assigned to a trained publicity man who is the public spokesman for the utility, but in medium-size and small ultilities, managers must use their own ingenuity to tell the story. If the community has two or more competing newspapers, radio, and television stations, written news releases may be required to prevent the news from being distorted. Many utility managers become personally acquainted with radio and television announcers and newspaper reporters who have occasion to report the utility activities. They explain how the utility operates and the reason for its activities, then rely on these men to report the true picture to the public. Frequently, a reporter can make an interesting story out of an incident that a utility manager considers insignificant. The author's experience has been that these stories are favorable to the utility and its management.

Adequate public relations will tell water users and the public the utility's plans for growth or change. The public will be told why growth and change are needed and the estimated cost and schedule of this growth. Oc-

casionally a utility changes its plans, and any significant change should be made known to the public. An informed public is a sympathetic public, and adequacy dictates that the public be kept informed. Annual reports, letter stuffers, and short messages on postcard bills are tools frequently used to maintain a high standard of public relations.

### Trained and Dedicated Personnel

A common weakness of utility public relations is the failure to give proper training to all personnel in the overall operation of the utility. Each man and woman in the utility family should know the component parts of the utility and understand their relationship to one another. They should be made to realize that they are an integral part of the utility organization and help make the utility operate. Management should realize that the employee is "Mr. Water Department" in his neighborhood, and that when his neighbors have a water problem, they go to him for the answer. If fully informed on the operation of his utility, the employee can accomplish a great deal in promoting public understanding and appreciation of the utility.

### Sound and Definite Policies

All utilities have policies, fundamental rules of operation. Whether written or oral, they must be clear, concise, and reasonable. Usually both utility employees and the public are willing to comply with policies that are understandable and sound. Vague and ambiguous policies confuse both employees and the public, and cause them to feel that management does not know what it wants. Public relations suffers from this.

### Attractive Properties, Equipment, and Personnel

The public knows very little about the inner working of a utility, but it does know how the utility looks. A water plant does not have to be ornate to be attractive, but all properties and equipment of the utility must be kept as clean as operating conditions will permit. Adequate public relations cannot be maintained if dirty pickup trucks loaded with unsightly tools are permitted to cruise around town. Employees who are tidy in their appearance become good-will ambassadors for the utility. Some utilities provide uniforms for their employees, and this practice merits careful consideration by all utility managers.

### Friendly Customer Relations

Water users are people who can think, who have pride, and who like to believe that they are appreciated customers of the utility. To maintain friendly relations with water customers and show them that they are appreciated, the utility must:

1. Train its employees to be friendly and businesslike. The pleasing voice that answers the utility telephone and the friendly but businesslike cashier can do more to promote good public relations than a dozen speeches by the manager.

2. Permit every person to present his problem to the proper employee. Permitting a water customer to present his problem, either by telephone or in person, may be time consuming, but it is essential to maintaining adequate customer and public relations.

3. Not give answers too quickly. The customer should be allowed to state his case before he is interrupted.

4. Be sympathetic with the customer. Tell him that his problem is recognized. Genuine sympathy is soothing ointment to most irritated water customers.

5. Make a definite decision, immediately if possible. Water users respect and admire a utility employee who will make a decision, although the decision may not be favorable to them. If an immediate decision cannot be made, the customer should be told why it cannot be made. He should be told whom to contact in order to obtain a decision or when a decision can be made.

6. Always follow up any problem that cannot be solved immediately.

7. Admit mistakes. All utilities make mistakes, and the frank admission that a mistake was made is a powerful weapon for making friends.

8. Be honest. Never make a promise unless it will be fulfilled. If water service to a customer cannot be improved within a year, do not say that it will be improved in the near future.

9. Assist customers on matters not related to the water utility. Give careful direction to the man who is trying to find the city manager's office, even to the point of accompanying him if necessary. Explain to the lady who calls about a hole in the street how to contact the street department.

Public relations can be improved by rendering such extra services as: (1) notifying customers when their water will be cut off to permit repairs, (2) on-the-premises checking of high water bill complaints, (3) assisting the customer in determining whether or not there is a water leak on the premises, and (4) notifying affected residents when a fire hydrant has been installed in their neighborhood.

A water utility is no better than its customers think it is.

# Physiologic and Health Aspects of Water Quality

## Task Group Report

*A report of Task Group 2760 P—Viruses in Water, presented on Jun. 6, 1961, at the Annual Conference, Detroit, Mich., by H. O. Hartung (Chairman), Exec. Vice-Pres., St. Louis County Water Co., University City, Mo. Other members of the task group are H. A. Faber, H. E. Hudson, P. W. Kabler, W. W. Sanderson, Don Williams, and R. L. Woodward.*

THE increasing amounts and kinds of pollution reaching public water supply sources make necessary the need for additional and new criteria of water quality control.[1] The 1961 USPHS Drinking Water Standards[2] remain minimum standards of water quality. They do not mention several substances that run to waste in sewers and are consequently potential constituents of water supplies in at least trace amounts. The standards do not mention these substances because their physiologic and health aspects are either not known or not yet considered significant. High-quality water production in the future will depend on the ability of the water utility operator to know the sanitary significance of, and to measure quantitatively a wide variety of, new pollutants.

It may be argued that all new pollutants or potential pollutants should, by regulation, be kept from water supply sources, and that therefore additional water quality control is the responsibility of the public health enforcement officer. Desirable as this may be from the point of view of the water-consuming public and water utility operator, such policing has its practical limitations. Waste disposal by water carriage cannot always be prevented even when desirable. Disposal of used water must almost always be into natural drainage streams. In addition, runoff into surface streams from dirty city streets, contaminated industrial acreage, and farms treated with agricultural chemicals cannot be prevented. Similarly, ground waters are exposed to the effects of waste water disposal into streams because of infiltration.

It may also be argued that all waste water should be treated prior to disposal; thus, additional quality control of raw-water supply becomes the responsibility of the waste treatment plant engineer. Although waste water treatment is indispensable to quality control of public water supply, no practical degree of waste water treatment known today will restore the original quality of waste-carrying waters.[1] Some pollutants are not even susceptible to biologic or chemical oxidation. Indications are that quality control of drinking water in the future will be dependent on the combined production of waste water and water supply treatment plants. Pollutants that cannot be removed in the waste water treatment plant, and that are

not kept from public water supply sources, must be removed in the water treatment plant. New treatment methods may be needed in both plants.

### Need for New Water Quality Criteria

The first step in the development of water supply control techniques for the future is the development of new water quality criteria. New criteria are needed not only for new pollutants that are deleterious to health but also for more common pollutants that are relatively harmless in small quantities, but which in larger quantities become objectionable. New knowledge must be acquired so that the harmful concentration of any substance can be determined. Criteria must be based on the possible intake of substances from sources other than water and must also take into account synergisms or antagonisms.

Some of the areas in which new criteria are needed were discussed at the Conference on Physiological Aspects of Water Quality, held at Washington, D.C., on Sep. 8 and 9, 1960.[2-13] The conference was sponsored by the Sanitary Engineering and Occupational Health Study Section of the National Institutes of Health, USPHS. The purpose of the conference was to focus attention on the significance of what is known and what should be learned about the physiologic effects of certain constituents of water—especially minerals, trace elements, insecticides, and organic substances. Pertinent information was also obtained from literature reviewed by AWWA Task Group 2760 P—Viruses in Water. This task group was directed in May 1960 to:

1. Review the literature and make a survey of studies that relate to virus diseases transmitted by drinking water
2. Investigate whether any of the presently used water treatment processes remove or inactivate any of the viruses
3. Attempt to learn if there are usable, safe, water quality criteria against virus disease transmission
4. Stimulate interest and make educational reports to the AWWA Purification Division on viruses in water
5. Encourage studies and investigations pertaining to virus disease transmission and public water supply.

### Viruses in Water

Infectious hepatitis is the only virus disease that has been proved to be transmitted through public water supply. Waterborne outbreaks of poliomyelitis have been suspected in at least two or more epidemic outbreaks.[14] In addition, public health authorities have postulated that certain other enteric virus outbreaks may have been associated with a common carrier such as water.

In every case of proven or strongly suspected waterborne infectious hepatitis or poliomyelitis transmission, the public water supply has not conformed to existing USPHS bacteriologic standards. Gilcreas and Kelly[15] pointed out, however, that under certain conditions viruses survive longer than coliform organisms. It is possible for viruses to be present in raw drinking water in very low concentration even though the water is relatively free of coliform organisms. Whether or not such virus concentrations in water can cause disease probably has not been determined by epidemiologic study. Nichols and Koepp[16] have stated that filtration methods will remove bacteria much more readily than the virus particle. This conclusion was based on a study

by Sabin that determined the diameters of enteric viruses to be 18 mμ or less, with the exception of the polio virus, which has a diameter of nearly 30 mμ. The diameters of the coliform group of bacteria are about 1,000 mμ or 50 times greater than most of the intestinal viruses known. Other investigators have questioned whether virus size is a measure of filtrability. It is entirely possible that although coliform organisms serve safely to indicate bacterial pollution, the absence of coliform organisms in water is no assurance of the absence of intestinal viruses.

Graham Walton,[18] of the USPHS Water Supply and Water Pollution Research Branch, made a survey in 1954–56 of more than 80 water treatment plants in the United States reported to have adequate bacteriologic data on coliform organisms and which treat raw waters having coliform densities in excess of USPHS recommendations. He found that:

> Although laboratory studies indicate that the residual chlorine levels required to kill or inactivate certain viruses are higher than those required to destroy coliform bacteria, there are no epidemiological data indicating that viruses survive treatment provided by a modern, well operated water plant. Additional research is needed before this apparent inconsistency can be reconciled.

An inquiry about virus disease transmission by drinking water was sent in September 1960 to the health departments of 50 states and 10 Canadian provinces by AWWA Task Group 2760 P. Of 46 health departments that replied, seven stated that one or more waterborne infectious hepatitis outbreaks had occurred in their areas of jurisdiction. An additional six departments indicated knowledge of one or more virus disease epidemics in their states which could have been waterborne. The other health departments concluded either that there had been no waterborne disease outbreaks in their states or that they lacked information. The department reports indicated that where water was shown to be the virus carrier, the water did not meet USPHS bacteriologic standards.

Although evidence at hand seems to indicate that waterborne outbreaks of infectious hepatitis from the use of water conforming to USPHS standards is unlikely at the present time, increasing pollution of raw water supplies is cause for concern. The question is whether the safe level of enteric viral agents in water supplies can be controlled by existing, commonly used water treatment practices. This concern is valid, for it has been shown that primary sewage treatment does not significantly remove viruses and that activated-sludge sewage treatment removes only about 90 per cent of enteric viruses added to sewage in experimental tests.[14]

Present knowledge is too limited to allow the setting of basic minimum chlorine doses for virus control in water treatment plants. Kabler and others[17] have been able to inactivate several of the infectious virus strains in 30 min with as little as 0.3 ppm free chlorine residual at pH values no higher than 8.0–8.5 at 20°C. At higher pH values, at lower temperatures, or with combined chlorine disinfection, virus kills have not been predictable.[17]

At least one investigator conjectured that there is a correlation between the amount of turbidity present in filtered

water and the incidence of infectious hepatitis. He observed that where filtrate turbidities were kept less than 0.2, there was a low incidence of the disease. Therefore adequate coagulation, settling, and filtration in addition to proper chlorination have been reported as desirable for the elimination of the infectious enteric virus.[18]

From the foregoing it seems that there may be a need for criteria pertaining to viruses in water to insure the safety of public water supply. It may be added that knowledge about virus detection and virus removal methods is also required as a prerequisite to future water quality control.

## Organic Contaminants

Probably most of the new contaminants reaching public water supplies are organic compounds. These come from chemicals used as insecticides, fertilizers, detergents, automotive fuels, lubricants, paints, and from many other types of industrial production. The identification and detection of physiologically harmful organic materials in water is a new frontier in water quality control.

The literature does not report any direct and acute physiologic damage to humans as a result of the consumption of organic materials in concentrations now found in public water supplies. Manmade organics, however, are known to be responsible for taste and odor in drinking water, off-tastes in fish, fouling of ion-exchange materials, foaming, high chlorine demands, and coagulation problems. Then, too, knowledge gained from the examination of chloroform-soluble organic materials in connection with studies of causes of tastes and odors suggests that a careful assessment of the long-term physiologic effect of organic contaminants in water is now timely.[4]

The carbon chloroform extract (CCE) technique developed by USPHS at Cincinnati may be the tool with which new organic criteria for water quality will be developed. Middleton,[4] using the CCE technique, found these materials in river and drinking waters: DDT, aldrin, orthonitrochlorobenzene, tetralin, naphthalene, chloroethylether, acetophenone, diphenyl ether, pyridine, nitriles, acidic materials, aldehydes, ketones, and alcohols. Safe limits of any of these materials in water remain to be established.

The 1961 USPHS Drinking Water Standards [2] limit CCE for the first time to 200 ppb. It has been observed that water containing more than 200 ppb of these materials will generally have an objectionable taste and odor. On the other hand, some waters having objectionable tastes and odors may contain less than 100 ppb of these organics. Because the long-time effect of drinking water containing chloroform-soluble organics has not been fully assessed, and because chloroform-soluble organics may comprise an almost unlimited number of chemicals, additional criteria for organics in water are needed.

## Insecticides and Pesticides

The increased use of insecticides and pesticides has led to at least potentially serious drinking water contamination through spillage, drift, and runoff from treated land. In 1957, about 46,000,000 acres of land in the United States were sprayed from airplanes for the control of such agricultural pests as the boll weevil, fire ant, Mediterranean fruit fly, Japanese beetle, grasshopper,

and mosquito.[13] Spraying for ground and other general applications account for an even greater use of insecticide and pesticide chemicals.

More needs to be known about the effect on water quality when a lake or stream receives insecticides, pesticides, and other agricultural chemicals from spillage or as the result of extensive normal use. The water supply profession needs to be informed as to what quantities of these materials—singly or in combination with other materials—constitute a public health hazard. DDT has already been recovered from the largest rivers in the United States in concentrations as high as 0.02 ppm. Although this concentration has been considered too small to affect humans,[12] the criteria for an unsafe amount of DDT in water based on long-term consumption should be studied further.

In addition to DDT, these chemicals for pest control are also in prevalent use and could be in public water supply sources: BHC, strobane, TDE, rotenone, toxaphene, heptachlor, dieldrin, and malathion. Some of these are not readily subject to biologic oxidation. Some, like rotenone and toxaphene, can be removed from water with activated carbon,[13] provided that the concentration of activated carbon is sufficiently large and the contact time is sufficiently long.

Public health workers have generally concluded that when insecticides and pesticides are not present in water in sufficient quantities to kill fish, they will not constitute a public health hazard in drinking water.[13] If this can be established as fact, and lacking other means for testing, public water supply laboratories may be required to install flowthrough fish aquariums containing fish of the proper sensitivity for water quality control. At the present time, the greatest danger from insecticides and pesticides seems to be from accidental spillage or from the washing out of spray equipment and tanks.

## Cancer Hazards

Hueper [12] reported that:

> Very little definite information is on hand concerning the existence and types of actual and potential cancer hazards to man which may originate from the presence of recognized or potential carcinogens in water. Carcinogenic substances may be introduced into public water supplies not only with the discharge of urban and domestic sewage and the release of industrial wastes, but also by the pollution of ground and surface waters with atmospheric carcinogenic contaminants present in rain water.

Carcinogens that may be introduced into sources of drinking water come from certain inorganic and organic chemicals, radioactive materials, viruses, petroleum waste, and coal tars.

Hueper further suggested that a critical appraisal of the present status and prospective development of cancer hazards created by water pollutants appears timely. He supported his contention for such study by making several observations. One of these is from a study by Diels and Tromp from Holland, who found cancer death rates in municipalities with certain kinds of water systems to be lower than the death rates in municipalities without a water system or in those obtaining water from certain river supplies. In addition, Wedgewood and Cooper are reported to have isolated two carcinogens—3,4-benzpyrene and 1,2-benzanthracene—from sewage sludge in England. The possibility that these substances reached public water sup-

plies was not established. Hueper concluded that, although a study of cancer-causing substances in water is timely, the worst that can be stated at the present time regarding cancer hazards from specifically polluted water is that the prolonged consumption of such water will contribute to the exposed individual's total carcinogenic burden from all sources.

### Other Criteria

The 1961 USPHS Drinking Water Standards [2] consider the growing number of potentially harmful chemicals in sources of drinking water. The committee formulating the standards established safe limits for all chemicals where reliable information about toxicity was available. The 1961 standards have added concentration limits not appearing in the 1946 standards for these substances: alkyl benzene sulfonate, barium, cadmium, cyanide, silver nitrate, CCE, and radioactivity. Still missing from the standards are limits for the inorganic chemicals vanadium and molybdenum.

### Mineral Requirements

Although the water utility is predominantly concerned with limits for impurities in waters, at least one recognized nutritionist has suggested drinking water as a food source of trace elements required by the human body.[6] His suggestion seems to imply not that such trace elements should be added to public water supplies as fluorides are now added, but that their presence or absence be taken into account in prescribing proper diet. Among the chemicals mentioned as possibly present in drinking water and of physiologic benefit to the human body are trace quantities of iodine, calcium, iron, magnesium, zinc, and molybdenum. Obviously the water utility operator needs not only criteria for establishing desirable amounts of trace minerals in water but also safe-limit criteria.

### Summary

There is a definite lack of knowledge from which criteria for limited amounts of some potentially toxic chemicals or excessive amounts of some common minerals in water can be formulated. The physiologic effects of consuming, over long periods of time, many potentially toxic materials is not now known. Increasing pollution of raw water sources from growing population centers, expanding industry, development and new uses of chemicals, and higher standards of living resulting in greater usage of chemicals make further study imperative. Many chemical constituents of water, such as those composing CCE, have never been identified. Even the methods for the analysis of these organic materials remain to be developed before criteria can be established. Development of improved technology for water quality control should be accepted as a challenge by the scientist and engineer both in and outside the water utility field.

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# Development of Water Quality Ideals

*Elwood L. Bean*

*A paper presented on Jun. 6, 1961, at the Annual Conference, Detroit, Mich., by Elwood L. Bean, Chief, Treatment Sec., Water Dept., Philadelphia, Pa.*

AT the 1960 Conference at Bal Harbour, Fla., the author outlined the progress in thinking of Committee 2225 M—Purification and Treatment with reference to quality water standards as professional standards. The need for professional goals is definite.

The 1961 Drinking Water Standards have been published.[1] These standards are not such as to alter the situation appreciably. It is stated that the mandatory limits are: "Limits which, if exceeded, shall be grounds for rejection of the supply." The recommended limits are: "Limits which should not be exceeded whenever more suitable supplies are, or can be made available at reasonable cost." These cannot be considered as goals for a profession. They are only such as may assist USPHS in the fulfillment of its functions within governmental restrictions.

Thus the committee, in its assignment of delineating a quality water, cannot take the easy way and refer to the Drinking Water Standards on numerous matters of quality. To delineate a truly good-quality water, it seems necessary that definite designations be prescribed by the committee on 30 or more different characteristics.

It is now agreed that the point of applicability of goals of quality should be at representative points in the distribution, as near to the ultimate consumer as possible. It is the consumer who is the ultimate judge of the product, and it is he who must be satisfied if the utility is to enjoy a good relationship with its public.

### Standards or Ideals

The committee encountered great difficulty with the problem of setting up any schedule that would be designated as a standard. There is an aversion by many against setting up any standard. This designation carries more than an implication of a passing grade—more than a stigma of failure for those who cannot meet the schedule set up, perhaps through no fault of their own, but because of source characteristics or other reasons. There is also the possibility of liability or even legal involvements. On the other hand, ideals or goals are desirable in all branches of activity. The author has long since stopped thinking of any schedule regarding quality as a standard, but thinks of it as an ideal. In the author's opinion, this change in the background is necessary for any formulation that can be widely applied, considering the great variation of factors involved for the thousands of varied locations, as a yardstick of qual-

ity and never as an implication of condemnation.

With ideals rather than standards in mind, the qualities of an ideal water are being delineated on a level such that many supplies can conform on many points, but no supply will conform on all points, because of the variation in the natural sources. In rating a supply, therefore, none will have a perfect score. These are not ideals carried to infinity. In fact, the sensitivity of present test methods might control the limit on some characteristics. They may be termed practical ideals or goals.

In theory, these basic quality figures would be applicable to individual test results. In practice, they might be better applied to a series or group of analyses, because of the lack of duplicability in sampling techniques and testing results.

## Rating System

Development of a rating system is progressing around a flexible concept that the rating should be applicable to as many systems of analytic data or spans of time as possible. If a series of daily tests with the monthly average is available, the rating should be applicable. If the monthly averages and their yearly averages only are available, the rating system should still be applicable. If only single determinations of some or all characteristics are available to the rater, some method of application should be available. Where no data are available on some characteristics, the rating system should be applicable to those available, although a penalty should attach for not having full data available. The committee is not construcing an inflexible, legal, enforcement rating. The rating should be possible to apply using whatever span of time or number of analyses might be available to the rater.

If the rating were to be used for competitive comparisons, as has been mentioned as a possibility, then rules of the competition would necessarily have to delineate the period covered, the frequency of tests, and other matters required for fair competition. The committee is now of the opinion that 1 year should be the basis for any such comparative ratings.

For general application, in determining the magnitudes set up in the rating, one of the basic concepts being considered is that programs for analyses should include:

1. Daily tests on those characteristics that may be subject to rapid or frequent change. This group would generally include turbidity, sediment, color, pH, bacteria, chlorine residuals, odor, taste, and possibly alkalinity, iron, and manganese.

2. Series of semiweekly tests on characteristics that change somewhat less frequently or are of less vital significance in: (1) potability, (2) appearance, and (3) use of the water, within the range of changes in characteristics that may occur in the particular water. This group might include some of the characteristics mentioned previously, as well as ammonia, nitrite, nitrate, chlorides, dissolved oxygen, and carbon dioxide.

3. Series of weekly tests on characteristics that change somewhat infrequently or are of less vital significance than those mentioned above.

4. Monthly tests of characteristics that are relatively constant, such as minerals.

The series of daily tests or semiweekly tests mentioned need not be interpreted to mean a series of tests taken daily or semiweekly at one point, but should be groups of tests taken at many representative points in distribution, some points being tested daily, others semiweekly.

The system should be equally applicable to yearly averages of a series of monthly averages on the various characteristics. This would generally produce somewhat less penalty points, as the daily variation of quality would be averaged out, exceeding the penalty points less often.

If only a single test result is available for rating, the application of any point system becomes a matter of individual judgment as to the points allowed, unless the result is below the basic limit, or above the amount allowable with the maximum penalty points specified. Lack of any data would be a more serious matter than the specific point rating allowed on a single test.

Application of any type of rating requires individual determination by the rater of the applicability of many points to the specific water or system being rated. The individual who would have sufficient imagination or interest to attempt the application of a rating, however, would probably also have sufficient imagination to resolve its application.

## Analytic Data Sources

In connection with sampling and and analyses, the 1961 Drinking Water Standard[1] states: "Compliance with the bacteriological requirements of these standards shall be based on examination of samples collected at representative points throughout the distribution system." This seems definite and well worded. In a following section, it is stated that ". . . provided . . . laboratory methods and technical competence of the laboratory personnel are approved," samples examined by the reporting agency, the local government laboratories, the water supply authority, and commercial laboratories may be included. In the section on chemical characteristics, it is stated: "Where the concentration of a substance is not expected to increase in processing and distribution, available and acceptable source water analyses performed in accordance with standard methods may be used as evidence of compliance with these standards." Data of USGS in "Water Supply Papers" and of USPHS in "National Water Quality Network" are mentioned. Application of these principles of using available data would materially reduce the burden of assembling a rating for many systems.

## Contents of Committee Report

It is expected that a later report of the committee will contain sections on the following subjects: (1) introduction and statement of purposes, (2) outline of functional specifications of an ideal water, (3) statement of specific quality limits on the various characteristics of an ideal water, (4) statements regarding techniques, with reference to some of the controversial or not completely standardized procedures, such as those for ABS, organics, and odors, (5) rating schedule for water quality, purification, and treatment, (6) statements explaining intent of the various classification ratings and application of penalty assign-

ments, and (7) statements as to applicability and uses of the rating, meaning of the ranges in rating, and total rating scores.

**Ideal Qualities**

According to present thinking, some of the limits for ideal quality are:

1. Turbidity—0.1 scale unit or less. Is this too strict? Not at all; one supply is known to be supplying water with turbidity of less than 0.1 on approximately 90 per cent of its tap samples.
2. Suspended matter—0.1 ppm or less.
3. Color—3 scale units or less.
4. Odor—no change on carbon contact (method to be defined).
5. Taste—none.
6. Fluoride—the standard scale as recommended by USPHS is based on years of study and seems the present undisputed ideal. There would be a penalty for water with concentrations over the optimum.
7. Phenolic compounds—as tastes may be determined with only 1 ppb of some phenolics, this material should be present in a concentration of no more than 0.5 ppb.
8. Chloroform solubles and alcohol solubles from carbon adsorption—these materials are conglomerates that cannot generally be analyzed sufficiently to know the many compounds present. But it is known that they might contain toxic substances; therefore, the totals should be strictly limited. Values of 40 ppb for chloroform solubles and 100 ppb for alcohol solubles are being considered as ideals.
9. ABS—the only practical measure of the presence of detergents, presently, is the methylene blue test. This is applicable with respect to about 75 per cent of household detergents. No adverse physiological effects are known as the result of drinking water that contains detergent, although tastes will occur above an ABS content of about 1 ppm. Foaming may occur at a concentration of about 0.5 ppm. The ideal water should contain no more than 0.2 ppm.
10. Corrosion and scaling characteristics—control of these items seems to require principally a balancing of alkalinity, carbonate, dissolved solids, and pH. There are various methods of control. The method of control will not be delineated. The measure of corrosion or deposition will be the amount shown on standard coupons inserted in mains, probably for a period of one year.
11. Bacteria—coliform organisms are, of course, the most practical indicators of pollution, and the effectiveness of treatment and sterilization. It is believed the ideal quality water should contain far less of these indicator organisms than is allowed by existing standards, perhaps no more than 1 per cent as many.
12. Radioactivity—data as to safe or unsafe concentrations of radioactivity are all too sketchy. A US Department of Commerce handbook [2] gave as a critical factor for lifetime use a gross activity of 0.1 $\mu\mu c$/ml. The factor presently under consideration for the ideal is one half of that amount. Incidentally, this would be 5 per cent of the gross beta activity maximum in the Drinking Water Standards. Limits for Strontium 90 and Radium 226 are also under consideration.

13. Organic phosphorus, chlorinated hydrocarbon insecticides, and virus control may be omitted, as the committee feels that information on these does not presently warrant a determination as to what should be ideal. These are being studied and data may later warrant their inclusion.

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1. US Public Health Service. Drinking Water Standards, 1961. *Jour. AWWA*, 53:935 (Aug. 1961).
2. Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. US Dept. of Commerce, Bureau of Standards. Handbook 52, Washington, D.C. (1953).


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# Water Quality Definitions and Research

S. Kenneth Love

*A paper presented on Jun. 6, 1961, at the Annual Conference, Detroit, Mich., by S. Kenneth Love, Chief, Quality of Water Branch, US Geological Survey, Washington, D.C.*

IN recent years much has been written and more has been spoken about water quality. This new attention to water quality is encouraging, but the term *water quality* has not been defined in simple language that means the same to all people. Like many other terms, *water quality* is used in one way by the public health engineer, in quite another way by the industrial engineer, and in yet another by the agriculturist. This article presents a discussion of the uses of *water quality* in several fields of interest and outlines the kinds of research studies being made to satisfy major interests.

## Quality of Natural Water

In order to understand the effects of what man puts into water, it is necessary to know first what is naturally in it and the quantities and sources of these added materials. Freshly evaporated water vapor from the ocean or other bodies of water immediately mixes with gases of the atmosphere. When water vapor condenses, it absorbs oxygen, carbon dioxide, and traces of other atmospheric gases. Running over the surface of the ground or percolating into the ground, water dissolves soil and rock materials. If these materials are derived from crystalline rocks, the water flowing over or through them will contain low concentrations of dissolved solids. If the materials are derived from sedimentary rocks, the water will contain moderate or large concentrations of dissolved solids.

Natural-water quality is affected by particulate matter transported in streams. Practically all surface water contains suspended sediment that results from natural hydrologic and geologic processes of erosion.

The introduction of dissolved and suspended material into water by natural processes is essentially beyond man's control. These natural contributions are frequently grouped together and labeled "natural pollution." The author objects to using the term *pollution,* with its pejorative connotation, in connection with functions that have been in existence since the world began. *Pollution* should be used to imply the degradation of water quality only by the activities of man, as this qualification seems to be accepted by the general public.

## Water Quality in Public Health

Good water quality has been identified by the general public with water that is safe to drink. State boards of health and public water supply agencies have maintained increasing vigilance over water consumed by the general public. The success of this vigilance is demonstrated by the drastic reduction in waterborne diseases in the past 50 years. Few would disagree that chlorine, in one form or another,

has been the principal disinfecting agent responsible for the successful control of waterborne diseases.

To the public, a potable water supply that contains no harmful organisms is identified with water of good quality. Water that does not meet high standards of excellence from a health viewpoint is labeled as being of poor quality. This public concept is understandable and also fortunate. It keeps operators of water treatment plants alert and requires that they maintain the highest possible standards of quality at all times.

## Water Quality in Industry

In industrial parlance, *water quality* is used without reference to the concept of potability. A water of suitable quality for industrial use may or may not be acceptable for human consumption. Generally, except for water used for cooling, industrial water must contain smaller amounts of dissolved solids than water that is acceptable for public supply. Industrial water uses may be divided into four groups: cooling, process, production of steam, and generation of electric power.

Water for cooling can be used in a wide range of quality. Dissolved solids may range from only a few parts per million to the amount in sea water, which is about 35,000 ppm. It need not be free of pollutants, either organic or inorganic. It is frequently advantageous, however, to remove or inhibit the growth of bacteria and other organisms to reduce troublesome fouling of cooling equipment. Treatment to prevent or reduce corrosion is also common.

Process water—water incorporated into or coming in intimate contact with manufactured products—is subject to many kinds of quality requirements, usually rigidly controlled. Water used in the manufacture of textiles must be low in dissolved solids and free of iron and manganese. The pulp and paper industry, especially where high-grade paper is made, requires water in which all heavy metals are absent or present in very small concentrations. The beverage industry requires water free of iron, manganese, and particulate matter, and free of bacteria and organisms of all kinds.

Water quality requirements for the production of steam are becoming increasingly exacting. This is especially true for water used in high-pressure boilers where pressures exceeding 1,000 psi are common. For these high pressures, dissolved solids must be kept very low, often at less than 0.5 ppm, and dissolved oxygen at less than 0.05 ppm. No natural water can meet these requirements. To meet such rigid specifications, the raw water has to be treated in various ways. The better the quality of the raw water, the less costly are the treatment processes.

Hydroelectric-power generation has very few requirements as to water quality. An adequate head of clear water is the principal factor. Turbid water can be tolerated but is undesirable because it erodes turbine blades. Silica in water sometimes causes trouble by adhering to turbine blades. Generally, water suitable for other purposes is satisfactory for hydroelectric-power generation.

## Water Quality in Agriculture

When irrigation was being developed in the western states, little attention was given to the quality of the water. If the water was wet and there was plenty of it, not much else mattered. Attention might well have been given to experiences of ancient civilizations where water quality was a prime

factor in national survival. Archeologic studies indicate that the decline of the semiarid country of Mesopotamia, which developed elaborate irrigation systems, was in large measure caused by destruction of soil fertility and by unfavorable salt balance. Similar catastrophes occurred in Egypt and among the early Indian civilizations in what are today the southwestern states.

In the western states, hundreds of acres have had to be removed from agricultural use owing to accumulation of salts in the soil. Soil impairment known as white alkali is fairly common.

Knowledge of the quality of the applied water and provision for adequate drainage have contributed much to maintaining crop lands in productive condition. Soil amendments have reclaimed some land that had been forced out of production.

Water quality information required for intelligent irrigation practices includes data on electric conductivity, calcium, sodium, bicarbonate, sulfate, sodium adsorption ratio, boron, and salt balance. In order to calculate salt balance, data on the quantity of water applied, water removed by drainage, and losses by evaporation are also required.

## Water Quality in Wildlife Management

Before the last decade or two, not much attention was given to the quality of water as related to wildlife and aquatic life. With the great expansion in fishing, hunting, and outdoor recreation in recent years, people interested in these activities have become more vocal. The principal quality factors that favor wildlife and aquatic life are high dissolved oxygen, freedom from turbidity, low dissolved solids, and absence of all forms of man-made or man-caused pollution.

Wildlife enthusiasts strongly recommend that rivers and lakes be kept in their original, natural state and that nothing be done to impair their high quality. This idealistic viewpoint becomes increasingly difficult to maintain as evidence is seen of dynamic geochemical and atmospheric forces at work. For example, the atmosphere contains varying amounts of very small particles of evaporated salts that originate in the ocean or on the land surface. Increasing amounts of man-made pollutants are also being discharged to the atmosphere. These include fission products from nuclear bombs, industrial waste gases, and automotive exhaust gases. Precipitation contains varying concentrations of these contaminants. Thus, it may be stated categorically that even fresh-fallen rain and snow are not the pure substances that the public generally considers them to be.

## Water Reuse

Practically all studies of water resources made in recent years emphasize the greatly increasing water demands for all purposes. Already the demand exceeds the currently available supply in many areas. In some sections of the country, water is used several times between its original withdrawal and its final discharge to the ocean. The practice of reusing water is certain to increase.

Water quality is degraded in one way or another following almost every use except the development of power. Most uses will result in the addition of suspended or dissolved matter to the water. Some uses add heat. The problem is to find ways to keep

the quality as high as possible through proper treatment and other means of pollution control.

**Research on Water Quality**

Water quality means different things to groups of people with different backgrounds and interests; investigations of water quality needed to determine the potability of water are quite different from those needed to evaluate waters for industrial, agricultural, and other uses. Although some of the basic data will serve more than one need, a specific data collection program seldom will serve all needs. Furthermore, it must be recognized that data alone, no matter how reliable or how voluminous, will not solve water problems. Only when pertinent, reliable data are intelligently evaluated and applied will water problems be solved. Thus, better communication and understanding are needed between the scientists and engineers making studies and the management groups who have responsibility for solving the problems.

The effective approach to water problems depends on many kinds of research studies. Research is needed to develop and use water resources effectively for all beneficial purposes. Some of the kinds of research that must be continued and expanded are:

*Geochemical research.* For a better understanding of how rock and soil materials are dissolved and retained in water, fundamental geochemical studies must be made. What factors control the equilibrium between liquid and solid? Oxidation-reduction potential, hydrogen ion activity, and solubility constants are a few such factors. How do they operate in nature? How will knowledge of these factors affect the withdrawal of water from and recharge of water to water-bearing formations? It is known from experience that in places, geochemical forces are partly responsible for decreasing withdrawal or recharge rates, but only limited knowledge of the factors involved is available.

Modern technology makes it essential to know what will happen when radioactive wastes are discharged into surface and ground waters. How will the wastes diffuse and mix with the receiving water? How much waste will be adsorbed on stream sediments, and under what conditions? Will adsorption be temporary or permanent? How fast will the radioactive sediment move downstream? How and under what conditions will the radioactive waste be taken up by animal or plant life, and when will it be released to the fresh-water or ocean water environment? These and many other questions need answering. Partial answers are already available, but much research remains to be done.

The biologic life processes in streams and lakes greatly influence the water. For example, troublesome tastes and odors associated with plankton blooms periodically plague water utility personnel. Such life processes also affect the geochemistry of water by depressing or enhancing the solubility of minerals in contact with water. Research is needed to answer specific questions about the role of aquatic organisms in the translocation of suspended and dissolved constituents.

Much research effort has been spent in developing water requirements for industrial use. The kinds of treatment that are used to tailor water for specific purposes are familiar. They include filtration, disinfection, degasification, softening, removal of heavy metals, demineralization, treatment to retard corrosion, and many others.

Research to improve existing procedures and to develop new kinds of treatment is increasing in magnitude and scope. For example, the federal government is supporting research in the demineralization of water. The detergent industry is looking for biologically soft materials that can be oxidized naturally or in sewage disposal plants into simple, nonobjectionable compounds. Users of radioactive materials are searching for safe, economical means for disposing of wastes.

Many people think that the techniques to produce and distribute water for public consumption and use have reached the ultimate. Dirty, polluted surface water can be made bacteriologically safe and usually palatable by appropriate treatment. Solid matter is coagulated, clear water is produced by filtration, carbon removes tastes and odors, chlorine disinfects the water, and chemicals render it noncorrosive.

Perhaps water utility personnel are too satisfied with their knowledge of treatment of public supplies. Jar tests for optimum formation of floc have been standard for many decades. Faster methods for determining the filtrability of water are needed. Recent research indicates that improved procedures for determining filtrability are being developed.

Taste and odor problems are increasing. Activated charcoal is effective in many instances, but it is messy to handle and relatively expensive. Superchlorination is also effective for certain tastes and odors but frequently leaves chlorine tastes and odors that may be as objectionable as the original troublemaker. Improved methods for removing tastes and odors are needed.

Additional research should discover cheaper and more efficient means for retarding corrosion and preventing incrustation of water mains.

## Conclusion

Any attempt to define the term *water quality* in simple language cannot succeed. The increasing complexity of quality requirements to satisfy the various uses of water makes it impossible to establish a definition that is applicable in every context. Instead, the scientific and engineering professions that deal with water should develop meaningful and understandable quality criteria for each kind of water use. Information on these criteria should be made available to all agencies and persons responsible for regulating the discharge of waste water to natural water courses. Substantial progress in this direction has been made, but opportunity for greater progress lies ahead.

# Three Applications of Instrumentation and Automation

Ellwood H. Aldrich

*A paper presented on Jun. 5, 1961, at the Annual Conference, Detroit, Mich., by Ellwood H. Aldrich, Engr. Cons., American Water Works Service Co., Philadelphia, Pa.*

THIS article illustrates the use of instrumentation and automation in three types of water supply operation. The first application is in booster station operation in the system of the Municipal Authority of Westmoreland County, Greensburg, Pa. The second is in wells and storage in the Haddon Heights division of the New Jersey Water Co. The third is in a new filtration and pumping plant recently placed in service in the South Pittsburgh Water Co. system serving suburban Pittsburgh, Pa.

Automation is largely the result of technological development stimulated by the necessity to combat rapidly mounting costs (chiefly labor), the need for closer supervision, and the desire to improve the product constantly. Instrumentation and automation are becoming more and more complex. Instruments and machines shoot a man into space and run entire plants automatically. Even the cowboy is bowing to automation. In the water supply field, automation has increased to such an extent that most people are unable to keep up with many of its advances.

Instrumentation by itself does not provide automation, but it is usually an important element, providing the sensing and activating mechanism by which automatic operations can be performed and controlled.

It should be pointed out plainly that increased instrumentation and automation is not necessarily a panacea for all water supply problems. Automation cannot take the place of judgment in performing many of the duties involved in water production and service. A machine has not yet been invented that can think; that is, exercise judgment and reasoning power. Automation can, however, perform accurately and quickly many tasks in which human efforts are slow, and in which failures can and do occur.

Transmission, control, and evaluation elements for automatic operation are available. Sensing devices are offered for measuring chlorine residual, pH, oxidation-reducing potential, conductivity, alkalinity, fluoride, turbidity, color, hardness, and sludge densities. Complete automation may involve automatic analyzers and computer mechanisms in the laboratory as well as the means for translating laboratory results into action in the treatment process. The measurement and control of pressure, temperature, liquid level, and fluid flow are quite common in the water supply field.

**Booster Station Automation**

The first example of automation is a booster pumping installation in the distribution system of the Municipal Authority of Westmoreland County, Greensburg, Pa. It is a rather small installation, requiring special treatment. The problems presented in this case were solved, it is believed, in a new manner.

Greensburg, located near the center of the area served by the authority (which serves a large part of Westmoreland County), gets its supply from three sources in different directions. The major supply comes from the Beaver Run Reservoir, 16 mi north. To provide sufficient water for the future at adequate pressure in the central Greensburg area, either substantial pipe reinforcing or an automatically operated and controlled booster station was required. It is necessary to maintain a hydraulic elevation of not less than 1,275 ft above mean sea level and not more than 1,300 ft in central Greensburg in order to give satisfactory service. A 5 mil gal tank maintains an elevation of about 1,315 ft at the southerly end of a 36-in. transmission main from the Beaver Run supply. Thus only 15–40 ft of head was available for friction losses in some 28,000 ft of parallel mains, generally only 12–18-in. in diameter, to the center of Greensburg. The planning was further complicated by two minor supply points, as well as by high areas and the need to limit pressures in the system because a considerable amount of cement pipe was in the system. The installation of a parallel reinforcing main was impractical because a main large enough to eliminate the need for some repumping would cost too much.

Automatic operation of a new booster station at rates of 3–10 mgd was provided by installing, among other units, two identical pumps, each driven through a flexible coupling by a variable-speed magnetic drive, in turn driven through a flexible coupling by 200-hp squirrel cage motors. The electric power control center provides automatic control of the two pumps by regulating pump speeds and the number of pumps in use so as to maintain a constant water pressure 5 mi away in Greensburg. No telemetering of pressure from the city to the station is involved. A certain static pressure at the pump discharge (with no flow) corresponds to the desired constant pressure in Greensburg. The increase in pump discharge above static represents friction, and varies as the 1.85 power of the rate of flow. The differential increase above static and the differential venturi meter pressures vary in approximately the same values. Any deviation results in changing the pump speed and delivery so as to restore the relationship. When the capacity of one pump is exceeded, the second pump starts up slowly. As it assumes part of the load, the speed of the first pump is slowly decreased to equalize the differentials and the pump speeds. The reverse happens when the load drops off. Automatic means are provided if one unit fails to function properly. Also, the pump controls can be adjusted if higher or lower constant pressure at the remote point is desired.

In simple language, the booster pumping installation is automated and controlled by a pressure-flow relationship based on a station head curve computed on predetermined friction losses of transmisson to a remote point. This maintains constant pressures at that point without telemetering assistance.

The various elements of the installation include a venturi tube; a recording pressure gage; a differential transmitter; a square-root converter; and an indicating, recording, and totaling flowmeter instrument. The devices for accomplishing the pump controls further include deviation controller and magnetic amplifiers.

## Remote Operation of Wells and Storage

The second example of instrumentation and automation consists of a supervisory control system for the entire Haddon Heights division of the New Jersey Water Co.

The Haddon Heights system gets its water supply from ten widely distributed well stations. Clear-water storage is provided by seven elevated tanks and six ground storage reservoirs, also widely separated.

The ultimate system will have fourteen well stations with a total of 32 wells and 25 high-service pumps. Each of the 57 pumps will have supervisory control with reportback. Each pump can be operated from the central control with a hand-off-auto selector switch.

The telemetered functions include station pressures, flows from all stations, and water levels in all tanks. Determinations of pH and chlorine residual, as well as iron removal filter operation, will be reported from certain stations. The transmission methods involve tone control equipment, either of the single-tone or tone-shift principle. Each telemeter function has its own tone channel which it does not share with any other function. The supervisory functions use tone-shift transmitters; by using a coding method, the number of separate functions handled by a given number of tone channels is increased.

From central control at a distribution center the operator can select to run the pump in manual position, shut the pump off, or select the automatic position. When central control is in automatic for any given pump, the pump will start and stop by signals from a liquid level controller or pressure switch at the pump. Each station has its own local control system from liquid level or pressure controller. In the event of a transmission line, equipment, or power failure at central control, all pumps are automatically put onto the automatic position with local control in effect. This is accomplished by the use of a guard channel, which must be present for any central control change of positions.

Five well stations have iron removal facilities whose filters must be washed at periodic intervals. While the operator at central control cannot start or stop a wash cycle, he will know when a unit is being washed. He will know the accumulated filter runs and thus will know when the filters should be washed and when the filters have returned to their normal operating position following a wash cycle. This involves one-way supervisory control of 61 valves.

The central control panel of the console type is 18 ft long and has 48 strip chart recording instruments. Each pump in the system has its own hand-off-auto selector switch and reportback lights. Each filter has a timer and light to indicate the valve positions.

## Automatic Filter Operation

For a number of convincing reasons, the major one being the increasingly higher costs of construction, self-contained purification units were developed and installed at Alexandria, Va.,

over 12 years ago.[1,2] Because these units were remote from the point of operation control, the development of instrumentation and control that would perform automatically the several steps in the washing cycle of the filter units was required.[3]

Over the past 12 years the first four units at Alexandria have been increased to twelve, which have a total nominal capacity of 27 mgd. No substantial difficulties have arisen in the automatic features included in the original design. The author's firm has installed similar automated units at fifteen different plants in its system—for example, in Peoria and East St. Louis, Ill.; Joplin, Mo.; Lexington, Ky.; Summit, N.J.; and Greenwich, Conn.—with a combined nominal filtration rate of over 150 mgd.

Some changes and improvements have been made over the years. Pneumatically controlled, rubber-seated butterfly valves are now used in place of hydraulic gate valves. Flow into individual units is controlled by level controls. Venturi meter-actuated, rate-controlling butterfly valves have taken the place of the conventional filter rate controllers. Miniature instruments are generally used. Self-contained illuminated and diagramed control boards present pictures of each plant's operating features.

## E. H. Aldrich Station

The new Shire Oaks station of the South Pittsburgh Water Co., dedicated in September 1961 as the E. H. Aldrich Station, is a complete, largely automatically operated and controlled water purification and pumping plant.

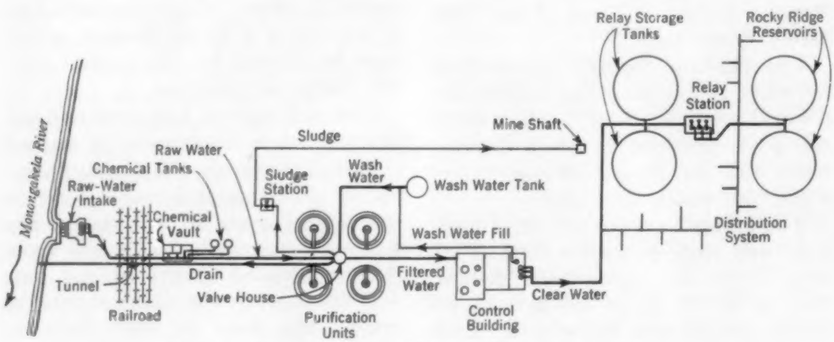


**Fig. 1. Plan of E. H. Aldrich Station, Shire Oaks**

*Present capacity of the station is 25 mgd, with accommodation for future expansion to 100 mgd.*

The Monongahela River, its source of water, is continuously polluted with acid mine wastes. Proper treatment calls for acid neutralization, coagulation, and at times, water softening. This station was designed to meet these special problems and is unusual in its use of several chemicals not normally used in public water treatment, and in its use of all-slurry or solution chemical storage and applica-

tion. A visitor will look in vain for the customary dry-chemical feeders and overhead storage hoppers for chemicals. In their place he will see steel tanks, lined and unlined, to meet the requirements of the liquid chemicals being stored. There are concrete slurry tanks for carbon, located under a railroad siding; equipment to slurrify, produce, and store concentrated softening reagents, and chemical feed pumps.

Control features include remote control of automatic filter operations, automatically paced application of chemicals, and complete, continuous recording of all essential operations at a central point. They also include the control of the remote operation of raw-water intake pumps and relay pumps, as well as high-lift pumps located in the same building. The customary water level, pressure, and flow recorders from numerous points are also provided.

## Plant Description

Figure 1 shows the plan of the plant. It has a capacity of 25 mgd, with provisions incorporated in the design to allow for future expansions to 100 mgd. The water is taken from the river through a sectional intake providing for three pumps in each section. Passing through bar racks and traveling water screens, the water is pumped to the purification plant by three vertical pumps, two of which are rated at 10 mgd, and one at 5 mgd.

At the intake, the pumps discharge through a 42-in. line about 1,000 ft long tunneled under nineteen railroad tracks to a chemical vault where pretreatment chemicals are added. Leaving the chemical vault, the treated water proceeds through a valve house where it splits into separate influent lines, each serving a purification unit.

Each purification unit (Fig. 2) is constructed as three concentric steel shells containing a center column through which the water is fed into the unit. Soda ash is applied here. The settling compartment contains a mechanism * with four arms, two of which are equipped with sludge rakes to convey settled sludge to the center well, from which it is blown off to waste. From the settling compartment, the water flows over a weir into the filter compartment and variable-width wash water gullet. As the water travels over the settling compartment weir, it is treated with sulfuric acid for conversion of carbonates to bicarbonates. Radial wash water troughs are provided in the filter compartment. The water leaving the filter compartment passes through a venturi tube equipped with a butterfly valve which, together, form a rate controller. Then it enters a 1-mil gal clear well. All filter valves are pneumatically controlled, rubber-seated, butterfly valves.

The entire plantsite, including the intake and provision for future additions to 100-mgd capacity, encompasses an area of 6 acres. This is equal to 0.06 acre per mgd capacity—an unusually small area.

## Chemicals

This plant is unique in its use, at times, of nine different chemicals, all in liquid form. All chemicals, except chlorine, are pumped into the system with metering pumps having remote variable-speed and stroke adjustment.

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* HydroTreater, Dorr-Oliver, Inc., Stamford, Conn.

Caustic soda, alum, sulfuric acid, and hydrofluosilicic acid are purchased and stored in liquid state. Carbon is purchased dry and prepared into a slurry at the plant. Sodium chlorite and sodium hexametaphosphate * are stored dry but fed in solution form. charges into a slurrifier. Through the use of a recycling pump, the soda ash is slurried into a monohydrate form by mixing with the soda ash solution, which is being repumped into the slurrifier. During this time, steam or hot water is applied through a bottom

**Fig. 2. View of E. H. Aldrich Station**

*Intake is in far background, across tracks and on river. Control building and two of four purification units are in foreground.*

sparging system to keep the temperature above 95.7°F, the freezing point of the monohydrate. The sparging produces a layer of saturated solution in the top of the tank which is 30 per cent soda ash solution. Soda ash can be added to the tank until 92 per cent of the tank's volume is slurry and 8 per cent is saturated solution.

Chlorine is purchased in 1-ton containers in the liquid and gaseous state and fed with standard chlorinators.

Soda ash is purchased in the dry state and stored † in two tanks. It is believed that this is the first installation of its type in the water supply field. The soda ash is unloaded from cars by a vacuum pump which dis-

Concentrated sludge withdrawn from the purification units is collected in a basin and pumped to an abandoned mine some distance away.

* Calgon, Calgon, Inc., Pittsburgh, Pa.

† Using a system designed by Diamond Alkali Co., Cleveland, Ohio.

### Centralized Control

The control building contains the high-service and wash water pumps, chemical storage and feed equipment, a clearwell, a laboratory, an office, and a central control room. The central control room (Fig. 3) is laid out in the shape of a hexagon, with five of the walls containing control panels. From this room, which has a gross area of less than 1,400 sq ft, every control required to operate the plant, including remote elements of the intake and relay station, can be performed.

### Centralized Graphic Panels

Due to the large number of locations having equipment under control from this plant, and to the amount of information required, there was only one solution to the problem of panel size and readability—miniature instruments on a graphic of the plant layout, color coded.

Miniature recorders permit all panels to be fitted into one room, even with provision for future expansion. Mounting the information in a graphic of the plant layout permits easy correlation of how each piece of information affects the rest of the system. Color coding of each flow line provides quick visual comprehension of the information.

The color graphic panel not only reduces space requirements and increases the ability of the operator to understand what he sees, but it also provides an attractive room and serves as a tool to facilitate explanation of system operation to visitors.

### Master Control Panel

The level of water inside the traveling screen at the river can be seen on the graphic panel in a vertical-scale type of indicator. When the screen is dirty, a red light on the graphic symbol is energized, and an alarm rings on the console. The amount of raw water pumped from the river is measured, recorded, and totaled. This paces the chemical feeders, as will be described later.

As the purification units cannot be seen from the control room, the operator is dependent on the instruments for his knowledge of operation. Level is indicated and controlled, effluent is recorded and controlled, the position of each of the four filter valves is controllable, and their position is shown on back-lighted legend plates. The loss of head is also recorded on the effluent flow chart. A high loss energizes a flashing legend plate, as well as an audible alarm on the main panel.

While the backwash program is completely automatic, it must be initiated manually. Under each loss-of-head light is a start button to initiate the backwash cycle for that filter. In between is a legend plate energized when the backwash valve is open or when the automatic backwash cycle is in operation. Controls allow only one unit to be backwashed at a time, and the system is interlocked so that a second backwash cannot be started inadvertently. This automatic system has eight important features:

1. It is as foolproof as is reasonably possible. Each step is interlocked so that the cycle cannot proceed without the preceding step having taken place. If, for example, the effluent valve does not close, the drain valve will not open. And if the drain valve does not open, the backwash valve cannot open. This interlock covers each step in the process and provides the assurance that a

backwashing sequence on completion did more than just go through the motions. Every step must take place in the proper rotation.

2. The filter is allowed to drop to a preset level before the effluent valve is closed and the backwash valve is opened. This minimizes loss of water on top of the filter.

3. Provision is included for backwashing at a low rate, a high rate, then the low rate again. Duration and amount of each rate is independently adjustable at the panel.

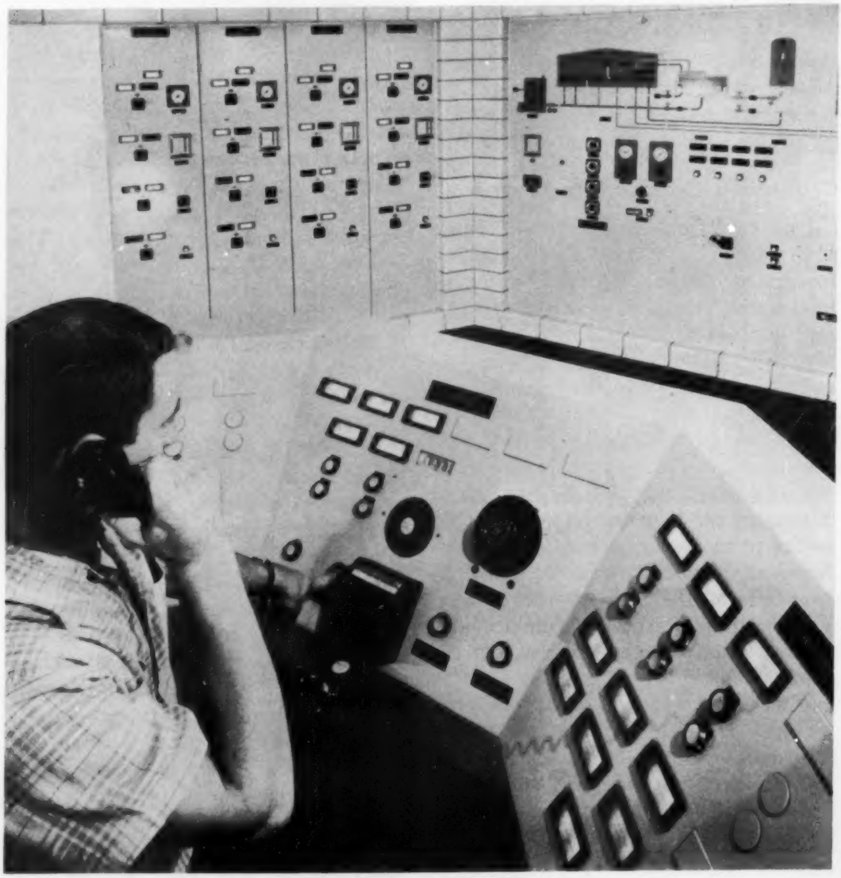

**Fig. 3. Control Room, E. H. Aldrich Station**

*Purification controls are on left-hand wall, graphic panel on right. Console is in foreground.*

4. A warning light is energized on the panel and at each filter 1 min before the end of the high backwash rate. If visual observation of the filter indicates the need for additional backwash time, the duration of the high backwash rate can be extended by depressing a pushbutton either at the unit or at the panel.

5. At any time during the cycle, the backwash can be interrupted by turning the manual-auto switch. This automatically returns the valves to their original positions in rotation and interlocks them, placing the filter under manual control. Again, failure of one step to take place prevents the next step from starting.

6. To reduce chart usage and provide greater readability for the wash water flow recorder, the chart does not start until the wash water flow starts.

7. The feeding of chemicals into a specific unit is automatically stopped during a backwash cycle, as will be described later.

8. At the end of the backwash cycle, the unit is automatically placed back in service with all valves in their correct position, filtering at the desired rate.

In addition to the automatic and manual valve controls for each unit inside the main control building, a separate panel for manual control is provided for each unit in the valve house. This house is located in the center of four units, where each panel is near the valves it operates.

The influent into each unit is individually throttled to maintain a predetermined and adjustable level. During backwash, this level drops to the weir between the internal chambers, and automatically increases to the desired height at the end of the cycle. The scale on the influent level instrument is specially marked to show the level of the wash water troughs, the weir, and the overflow to drain.

At all times the effluent flow rate is automatically controlled. Each filter control panel has a set point adjustment on the effluent flow recorder. The effluents from all filters, however, are summarized and indicated on the main panel. A selector switch at this point places all filters either under their own control adjustment, or places them all under the master control unit. This keeps a preset flow rate through the plant, independent of the number of filters in service. If one filter is shut down or taken out of service, the rest of the filters take up the reduction in flow. A limiting device, however, prevents the automatic system from requiring an undesirable flow rate from any filter. When under master automatic control, all filters operate at the same flow rate.

The water for backwashing is supplied from a wash water standpipe situated next to the units at a higher elevation. The level is visible on the graphic diagram on a vertical scale indicator. Preset high and low levels flash the appropriate light above and below the indicator and sound an audible alarm.

The backwash flow rate is recorded, totaled, and controlled at a preset rate. When a unit is backwashed manually, this flow rate can be manually increased or decreased to match the automatic system.

All effluents feed into a common clearwell, the level of which is visible in the graphic panel on another verti-

cal scale indicator. Again, preset high and low levels flash the symbol-mounted lights and energize an audible alarm. In addition, if the clearwell level rises above a preset level, all filter effluent flow rates are automatically reduced simultaneously until they reach zero.

The clearwell supplies the water for both the high-service and the backwash pumps. The high-service flow from the station is measured, recorded, and totaled on the panel. This completes the Shire Oaks operation, but there is other equipment on the panel.

To summarize, a clogged screen at the river intake will sound an alarm, chemical addition will be automatically paced, flow to the clearwell will be automatically increased or reduced to match the system demand, reduced filter effluent will reduce raw-water flow to each unit, and water will be automatically kept at safe levels. The only manpower needed in this operation is to initiate the backwash cycle and to silence the audible alarms.

As for the other equipment on the panel, two system storage facilities are shown on the graphic panel—one at the relay pumping station and one at Rocky Ridge. Levels of each are indicated and recorded in graphic symbols. In addition, flow from the relay pumping station is recorded and totaled, and pressure at this point is recorded.

This panel has its own integral alarm system. The type of audible alarm is different for each panel and console. Pushbuttons are provided for testing all the lights to make sure bulbs are live.

The entire control system has been designed so that the third set of four units will necessitate duplicate flow lines and venturi meters. Provision has been made on the panel for duplicate flow recorders and totalizers for raw water, Shire Oaks service, and relay station high service. Only additional filter panels will be required for expansion, one for each unit.

## Master Console

The console, mounted facing the main graphic panel, works in conjunction with and supplements the information on the panel. Each of the three sloping surfaces contains controls and lights for different physical locations. The left-hand side covers the river intake station; the right-hand side, the relay station; the center section, the main station.

For the raw-water pumping station at the river intake, there is control and indication of operation of raw-water pumps, screens and screen-wash pumps, plus an alarm for a low water level inside the screen and for transmission failure. Indications generally are by means of back-lighted legend plates, eliminating the need for both a bull's-eye light and a legend plate.

## Control Equipment

Although many signals are being transmitted in each direction between Shire Oaks and the intake, Shire Oaks and the relay station, Shire Oaks and Rocky Ridge, and Shire Oaks and the Hayes Mine station, only one pair of telephone wires between locations is needed. Each process variable—flow, level, pressure, and others—is continually transmitted by means of a separate tone signal. All supervisory controls are transmitted over the same tone signal.

Six design features make the supervisory system as foolproof as possible:

1. Although signals are transmitted on a time-sharing basis, less than 2 sec is required to transmit any command. An additional second elapses for the reportback. Normally, no transmission occurs until a new signal is to be transmitted. Therefore, any change in condition is transmitted immediately.

2. Because more than one signal may require simultaneous transmission, the system has a built-in priority order, permitting the signals from Shire Oaks to be transmitted first. All other signals are stored until transmitted.

3. If a discrepancy occurs between the instructions and the results, the audible alarm will sound and the specific light will flash. When the audible alarm has been silenced, the correct condition of the pump or motor will be indicated.

4. At any time, all reportback signals can be reconfirmed by depressing an all-scan button. This will erase all lights and re-energize them on the basis of the existing contacts at the transmission end.

5. If for some reason any transmission signal cannot be correlated at any receiver, all points are automatically scanned, reconfirming every reportback light or providing an audible and flashing alarm in the case of discrepancy between the original command and the reportback.

6. If a transmission failure occurs, the audible and visible alarm system will be energized at the Shire Oaks location.

Common to all console sections are four pushbuttons: One to silence the audible alarm in the console, one to test all lights, one to stop a flashing light after the horn has been silenced and corrective action initiated, and one to initiate the all-scan. In operation, this system is as foolproof as possible.

Provision has been made in the system for addition of more units, pumps, and equipment to bring the plant to its ultimate 100-mgd capacity, as the demands require.

For the relay station, controls and lights are presently provided for three high-service pumps. Lights only are provided to indicate openings of the cone valves for these pumps, as well as alarm lights for transmission failure, under frequency, and breaker open. The same type of supervisory control is involved here as described above, providing the same dependability of system operation.

The central console section includes controls for the station equipment. In addition to the four pushbuttons mentioned above, control is included for pump speed for the variable-speed motor, for wash water pumps, as well as indication for both sets of pumps. A telephone permits conversation with all essential points in the system while remaining at the control cubicle.

Although the elaborate supervisory control system provided for the intake and relay panel sections is not required, because of the direct connections and proximity of the high-service pumps and motors, the functional operation of the pushbuttons and lights is identical. For example, any discrepancy between commands and results will cause a flashing light and audible alarm.

## Chemical Feed Panel

The size and complexity of this project have necessitated many un-

usual features, but the chemical feed panel and type of control represented are unique features of the installation. The graphic diagram on the chemical feed panel duplicates the water flow lines of the main graphic panel, but includes details and controls that would only confuse the basic panel. This panel has been designed to handle the first four purification units, with provisions for the addition of four more. When the third group of four units is built, a second chemical feed panel will be required.

As on the other panels and console, back-lighted legend plates are provided to show pump and alarm conditions. Every attempt has been made to change automatically the rate of the chemical feed in ratio with the raw-water flow, and to record and total the chemicals fed. The only manual controls are those to select (in the chemical feed room) which chemical pumps will operate. A standby pump has been provided for each chemical. Manually removing a pump from automatic control disconnects its controls and contacts from the main chemical feed panel. The panel has a separate color line for each chemical to make it easier to understand what is happening.

The alum, carbon slurry, caustic, and soda ash pumps have adjustable speed and adjustable stroke control. The raw-water flow signal automatically adjusts the speed of each of the pumps that is operating. All of these pumps, except that for caustic, have a manual adjustment on the main panel for adjusting the stroke that changes the chemical dose. Therefore, the amount of chemical feed is directly proportioned to speed and stroke, is recorded, and is totaled on the main panel.

To adjust the caustic pump stroke, the pH of the raw-water flow is monitored beyond the points where the alum, carbon, and caustic are injected and beyond the point of prechlorination. The amount of caustic fed is adjusted by the pH controller to provide the exact pH value desired. High or low pH values actuate an audible alarm and flashing backlighted legend plates.

As soda ash is fed simultaneously to each of the four purification units, provision has been made to stop the flow to any unit when the raw water flow into that unit ceases. Any manual or automatic closing of the influent valve of any unit will automatically stop the flow of soda ash to that unit.

The sulfuric acid flows from a constant-head tank to each of the four units through control valves and injectors. This permits measurement and control of the acid when it is the least corrosive. The amount of flow to each unit is individually adjustable on the panel by changing the pressure drop across the valve. Whenever the raw-water valve to any unit is closed, the sulfuric-acid valve is also closed.

The hydrofluosilicic-acid pump has only stroke adjustment, made manually on the panel. This chemical, as well as sodium hexametaphosphate and sodium chlorite, is fed into the clearwell. The amount of the acid is recorded and totaled, and the operation of the pump is indicated on the graphic symbol of the pump.

The starting, stopping, and adjustment of the postchlorinator, as well as of the sodium hexametaphosphate and sodium chlorite pumps, are not accomplished at the panel. The operation of these pumps, however, is indicated in the pump symbol on the graphic panel.

In addition to the above controls, the pH values at six locations are measured and recorded on one strip chart: the raw water before addition of any chemicals, the treated water in each of the four purification units, and the clear water as it is pumped from the Shire Oaks plant. Provision has been made to add a second recorder for the second four units.

No additional provision for increasing the chemical feed pumps is necessary. All, except the soda ash pumps, can be adjusted to provide twice the output at a later date. Because two soda ash pumps will have to operate in parallel in the future anyway, lights for each pump have already been installed, although the second pump is temporarily used as a spare.

Each alarm system has a separate, flashing system and a distinctive-sounding horn, in addition to its own alarm silencing and light test push-buttons. All lights will be on back-lighted legend plate, eliminating the need for an additional nameplate.

In conjunction with the main control panel, the chemical feed panel provides a maximum of automatic control responses to a wide variety of conditions, alerting the operator only when trouble occurs. This frees the operator from routine or repetitive chores, permitting him to concentrate on other duties.

In the two panel sections reserved for the controls of the last eight purification units, to be installed in the future, a general plan and an elevation diagram of the major elements of the entire South Pittsburgh system are presented. The plan is generally to scale, but the elevation diagram is distorted. Lights are provided at the major points of interest in the system. A tape recorder public address system gives a short general description of the system, with a more detailed description of the Shire Oaks plant. This is keyed into the panel system to light up the appropriate light when talking about a specific facility. In this manner the author's firm has attempted to further a good public relations program, as well as to present a well developed description of the system and plant. At the same time, it relieves plant personnel of the tedious duty of repeating the story many times over.

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## Discussion

### *Kenneth F. Knowlton*

*Supt. & Chemist, Salem and Beverly Water Supply Board, Beverly, Mass.*

In his article, Aldrich has presented three examples of instrumentation and automation or control in what he describes as smaller systems. His smaller systems make that of the Salem and Beverly (Mass.) Water Supply Board appear almost miniature by comparison. The one treatment plant of this utility had an original described capacity of 8 mgd, but has operated at more than double this rate.

Many factors are common to the smallest and largest plants. The major factor, in the writer's opinion,

is the necessity for carefully fitting instrumentation and control to the individual plant. This must be handled in close cooperation between the engineers, the operators, and the equipment suppliers. Modern instrumentation has been little known in the water treatment field until the past 5 or 10 years. It is difficult for the engineers to learn all the new details, for the manufacturers to fully understand the demands of the water industry, and for the operators to overcome their distrust of new gadgetry.

Although the writer's system is small, it has made good use of new instrumentation and control features over the past few years. This has been of major benefit in operating safely at maximum rates.

## Evolution of Beverly Equipment

At first, a new instrument, a receiver-recorder or perhaps a controller, was installed with the case temporarily mounted on a wall. As experience grew and the picture of expansion became more clear, the utility was able to make a schematic sketch of what it wished to accomplish in recording and controlling plant operations. This sketch showed the information that the

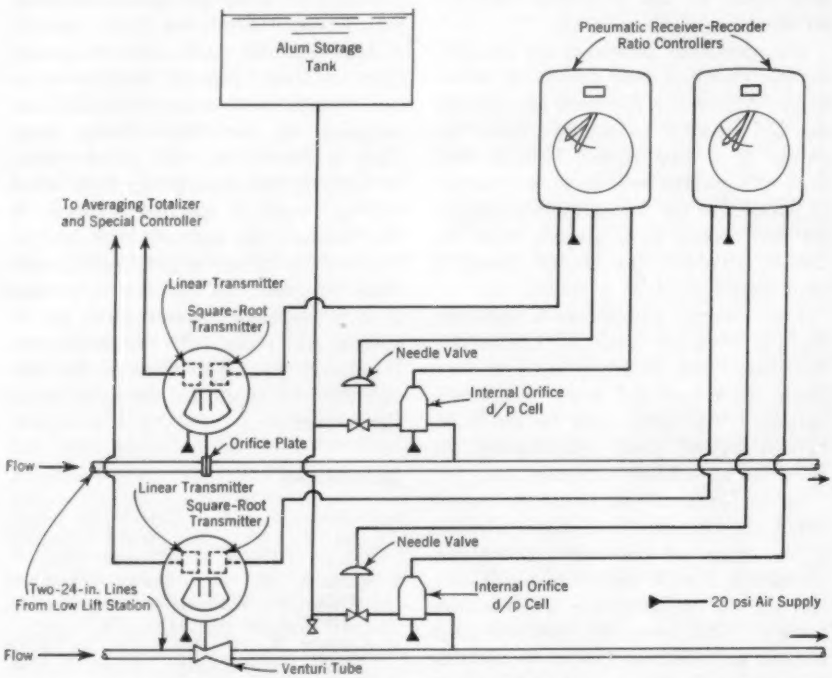


**Fig. 4. Flowmeters and Alum Control**

*Averaging totalizer and special controller connect with this system through linear transmitters in the primary flow meters.*

engineers wanted to record and the processes they wished to control by instrument. Copies were given freely to all equipment salesmen who came to the plant, and in about a year the engineers were able to work out what they believe to be a very simple, adequate, and inexpensive control panel. superintendent or any operator coming on shift could see at a glance what had been going on before. This has proven a great timesaver and convenience where only one operator is on each shift.

It would be misleading to say that the utility no longer has any operating

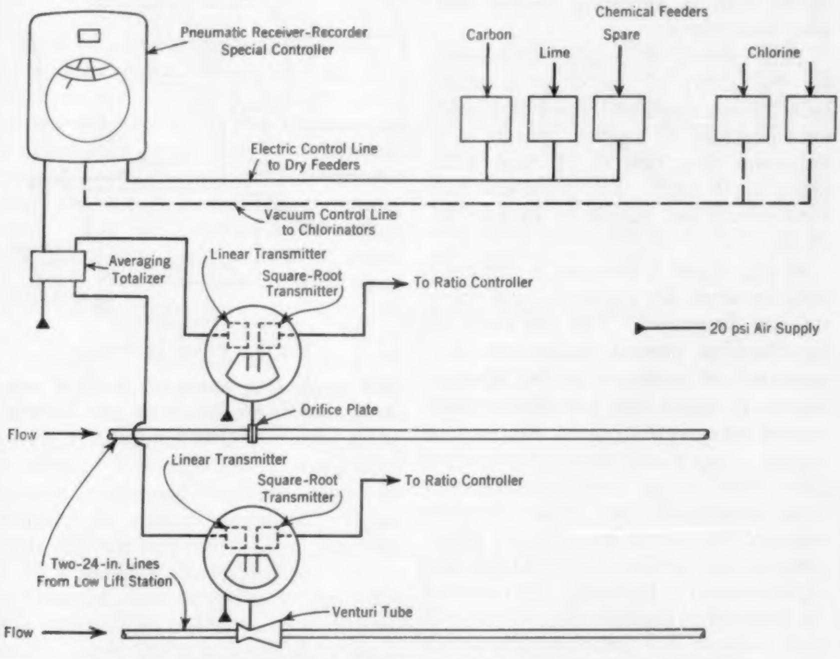


**Fig. 5. Total Flowmeter and Dry-Chemical and Chlorinator Control**

*Ratio controller is in the alum control system.*

This panel, 9 ft long by 6.5 ft high, contains ten full-sized circular chart instruments plus some smaller gages and signal lights. It stands in the office and has an 18-in.-wide desk top in front with book cases, desk drawers, and chart storage beneath. All the newer charts have 7-day records. These were specifically chosen so the difficulties. Instruments do not operate forever without some care, but the writer believes that there is less trouble with the new equipment than with the old, heavy, manual equipment. Many apparent troubles stem from the immediate knowledge of variations in feed rates and water quality. These variations formerly passed unnoticed.

Much of the utility's increased treatment potential can be attributed to the fact that all chemical doses and filter rates pace themselves automatically with the rate at which water is pumped into the treatment plant. Thus the demands for water can be followed accurately, allowing the operator to pay attention to water quality and quantity rather than to adjusting feeders and filter controllers.

This control is largely responsible for the ability of the physical plant, built 25 years ago and rated at 8 mgd with peaks to 10 mgd, to operate at a minimum flow rate of 10 mgd with peaks to 18 mgd. The plant has had a maximum net output of 16 mgd in 24 hr.

In Fig. 4 and 5, flowmeters and controls for alum, dry chemicals, and chlorine are diagramed. The two parts of the chemical control system are coordinated as indicated in the figures. Figure 6 shows the pneumatic filter control setup.

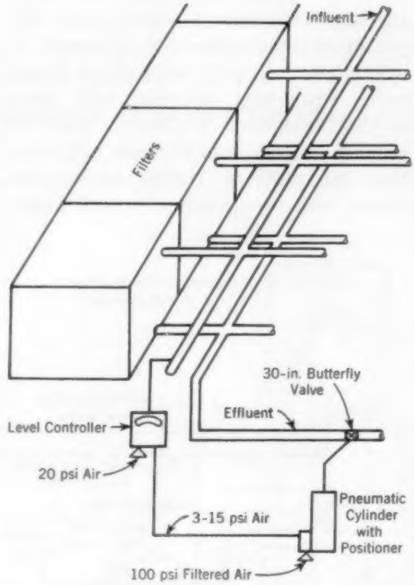


**Fig. 6. Filter Control**

*This method of automatic control was found suitable for the Salem and Beverly system.*

# Right of Way for a Dallas Pipeline

Henry J. Graeser

*A paper presented on Jun. 8, 1961, at the Annual Conference, Detroit, Mich., by Henry J. Graeser, Supt., Water Works, Dallas, Tex.*

As cities progress from villages to metropolitan areas, local supplies such as wells or nearby rivers often prove inadequate. This forces the communities to go afar for additional supply, and distant sources involve pipelines of high cost and large diameter. Cost considerations determine the most expedient routing of these facilities. A 100- or 200-ft detour often costs more than the land involved in rural communities. Mains of 60–90 in. diameter cost \$60–\$100 per foot. It does not take many feet of this type of line to buy a modest residential bungalow or a considerable portion of a farm. These mains also require additional working room in addition to normal easement. It is quite difficult to place a 72-in. main in a 50-ft public right of way.

Thought must be given to right-of-way acquisition. Many communities have a main under a building or in a basement because somebody thought "maybe it won't break until after I leave." This may have been the result of easements without specific terms, or of simple failure to realize what would happen when the city grew.

Federal road policy toward utilities has also aggravated certain easement and right-of-way problems. As road planners do not want the responsibility of considering pipeline easement problems, utility plänners should think of their own easements where lines can be located adjacent to highways. Service must be rendered because roads create frontages. Utility planners might as well face the fact that they cannot depend on free right of way from state and local agencies in all cases.

## Local Right of Way

For the most part, the right of way is available in city streets, but in areas like New York City, Chicago, or some of the older cities it is getting increasingly impossible to find a spot. Dallas city planners have never really envisioned what the downtown area would be. Dallas streets are narrow and the clutter of utilities has already become a practical impossibility. Thanks to rock formation in most of the downtown area, the problem has been solved simply by building a utility tunnel far below everything else and moving small and inadequate sanitary sewerage and water facilities into the larger system below. A portion of the tunnel back that encases the sanitary sewer is covered with concrete, thus constructing a combined utilidor with both water and sewer in the same tunnel. Of course, a future subway builer may find this structure inconvenient, but the tunnel planners

tried to leave as much room as possible for the subway above.

In rapidly developing areas in the community, where the property has not been platted, the Dallas water department has adopted a policy of requiring an easement for street purposes and absolute exclusion of any structures over the easement. This applies predominantly to water. Sanitary sewer easements will often allow construction of facilities over them as long as no footing rests directly on the utility.

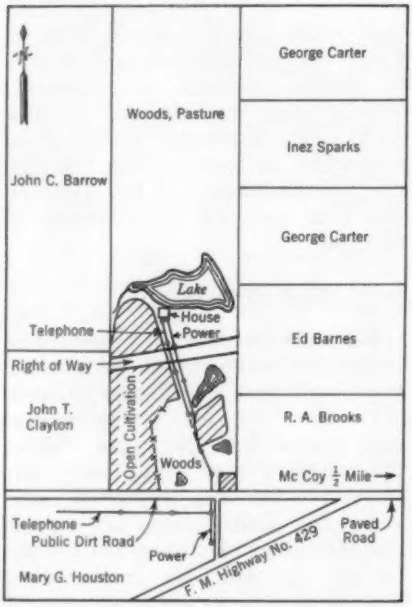


**Fig. 1. Work Map of Tract K-100**

*The tract shown has 180 acres, and the right of way across it 4.83 acres.*

The presence of a sewage utility under a possible structure is more excusable than a water line, because its location is dictated by terrain. This is not recommended procedure, but it happens.

## Long Pipelines

The more pressing problem now seems to be the routing through rural communities of pipelines linking large municipalities with distant sources of supply. The problem of dealing with farmers and traversing land in the most direct route is an old story with the gas pipeline and oil companies throughout the country. Generally, the price of gas and oil makes it more expeditious to pay a generous price for easements than to go around the land in question. Water, being a less lucrative product, dictates more careful economics.

Dallas is presently building a 33-mi pipeline from Sabine River to a new plant on the east side of the city. The first-stage pipeline is only 72 in. in diameter, but it was deemed advisable to provide space for an additional 72-in. pipe in a few years, as well as room for a power line. The decision was made to buy right of way 120 ft wide in fee simple. The city concluded that county easements should be purchased in fee rather than an easement taken for this width of right of way. The city has had considerable experience in settling crop damages where repairs or alterations have been required on lines in easements. When the continued expense of this is added up, together with the fact that very often an easement will receive nearly as high an award as fee simple, it was decided to purchase the right of way in fee. The easements required by many power companies are fee simple in all respects except the actual transfer of title and the payment of crop damages. The author doubts that any significant sav-

ings are realized by such procedure. With an underground utility, the farmer has free use of the land on the surface, provided he does not build any structures. In addition, he is relieved of taxes on the easement land. Of course, this does not receive wide acclaim, even from the farmer who is having his property traversed by this facility. Many farmers have had unfortunate experiences with other utilities and with highway programs, so resentment is stiffening throughout the area. A new type of lawyer, the professional condemnation lawyer, has sprung up. These people are adept in condemnation law and get their reputation by winning exhorbitant awards for properties required by the state. The interstate highway program has probably brought them a lot of business.

## Acquisition of Right of Way

A planned approach is highly advisable for rights of way. Although each city has its own forms and procedures, the Dallas procedure is outlined here. This procedure has been a successful approach to acquisition of right of way. A common beginning point is a land survey. On the Dallas pipeline, an aerial survey offered the most economical solution for preliminary location of the pipeline. Contours, obstructions, and other features of terrain important to the line location and cost could thus be chosen and evaluated.

When an approximate line has been established, field surveys were carried out. Using deed records from county files, right-of-way surveys were tied to an appropriate property line on each tract of land affected. With this information at hand, the land appraiser prepared an appraisal work sheet. From the data a work map is prepared (Fig. 1). All factors of possible value are noted by the appraiser, and the land is appraised in individual tracts according to its use and value. A separate sheet is available if building and other improvements are on the land. When the appraisal is completed, the package is forwarded to the negotiator and to the city engineering division for their files as a source of reference data. The completed report and appraisal includes, in addition to the work sheet, a cover page describing the tract and a general memo of report about the owner and his reaction to the acquisition of the property. Thus there is a legal description, a plat of survey, the appraiser's plat, and a certificate by the appraiser that he made the necessary survey. This report of appraisal is then available to the negotiator to contact the property owner in an attempt to obtain an easement or as in the case of Dallas, a contract to obtain the land in fee simple.

The contract to convey has certain special considerations that recognize rights of the property owner to use the land as long as it does not interfere with operation and maintenance of the pipeline. Gas and oil being an item of value, the contract allows the owner to retain all mineral rights, but reserves certain restrictions as to drilling or exploration which might damage the structures or impair the right of entry. The seller is given all rights to use the surface of the land for agriculture and grazing purposes in connection with his abutting property. The city, however, reserves unlimited egress and ingress when necessary without liability, but with proper precautions to prevent the escape of cattle or damage to fences. In this connection, the city is building cattle guards

or gates on the right of way where it is anticipated entrance will be required. These provisions are also in the warranty deed for the property.

It is difficult to assess at this time whether purchase in fee simple under these conditions makes a significant difference in cost. The city does not believe that it will. The presence of the line and the anticipated entry to the property is objectionable enough to the property owner. He would probably demand about the same price for an easement with similar restrictions as he did for fee simple. The more reasonable property owners see the advantage of surface use without the necessity for paying taxes. The experience of Dallas with a pipeline of a similar nature, but closer to the city, indicates that the cost of easement reserving the same rights would have been 80–90 per cent of the cost of fee.

The fact that the right of way will belong to the city in fee simple is also reassuring from the standpoint of control, reconstruction, and additions that might be necessary for the many years the pipeline will be in existence. Considering the life of this facility, any additional cost incurred in right-of-way acquisition in such a major facility will amount to very little on an annual cost basis. The fee simple acquisition appears to be a very good investment for the future, for it obviates certain situations in which previously experienced property owners refused to allow enlargement or installation of parallel lines when additional capacity was required.

### Negotiators

A city should try not to send to the country people who are not known in the area in which they are going to work. There are not always people with integrity or ability available in a rural community, but people who are at least known there can be employed. Although they live in the city, they have mutual interests with the people they are contacting. City personnel can back the negotiators up in the final appraisal, but should avoid direct contact with rural people as much as possible. Many farmers like to take some time discussing the right of way and any other subject that comes to mind. A lengthy, easy-going conversation is an essential part of negotiations, but it might make a hurried urban negotiator impatient. If time enough is taken, a reasonable settlement can often be reached through this process and condemnation court avoided.

The city must also be willing to be a good neighbor in the country. Unnecessary damage to property or encroachment on the land itself is something that cannot be tolerated. The farmer must be given every assurance that this will not occur; the agreements should be drawn in such a manner as to meet his requirements as far as possible.

Dallas has found that the person who makes the appraisal should not be the person who does the negotiating. This allows the negotiator to trade, and to use the appraiser as the point of departure while preserving his testimony for court without the danger of having his comments in negotiating misinterpreted on the witness stand. Thus the negotiator has the advantage of the appraisal, but is not bound by it; he does not need to defend it as he negotiates.

The entire procedure of contact deserves consideration from the stand-

point of the impression made on the people dealt with. The surveyors in their first contact can be an important factor in right-of-way negotiations. If they are rude, brusk, or violate the ethics of the community, repercussions can be expected when the negotiator visits these people to buy or obtain right of entry into their land.

### Condemnation

Every effort is made to buy land through negotiations rather than through condemnation, but condemnation is necessary in many cases where time is essential. As with negotiators, local legal counsel should be used instead of the city's staff for condemnation cases. The city may still do such office work as typing, preparation of suits and briefs, investigation of the law, and general support of the local counsel. The leading counsel may be the local legal representative, and his opinion as to whether a settlement is in order, rather than a court trial, should be properly considered.

All parties involved in appraisal, condemnation, and settling of awards should know one another and have confidence in one another. In Texas, the county judge appoints commissioners, experienced real estate men in the community, to review the appraisal figure, look at the land, and make an award of value. As a general rule the commissioners are fair in their decisions. If they are prejudiced or not confident that the appraisal has been fair in every respect, however, their awards may often be completely out of line. Most commissioners and juries have an aversion to greed and unfairness. When the responsibility for upholding the intent of the law is placed squarely on their shoulders, a fair and just award usually results.

When the award is not fair, the city may appeal in the county court. Here a jury trial provides for the usual number of impartial citizens to judge the facts in the case. Provision is made in case of an excessive award by the commissioners for the city to appeal the award and proceed to trial without depositing the amount of money awarded. The law prevents the city from delaying this action too long, however, and requires deposit of the award when possession of the land is obtained. No safeguards are available to the city to prevent the property owner from spending an excessive award and, except by judgment, from being unable to pay back the difference between the first award and a lower final award. The judgment is often too late when the first award money is spent for items of diminishing value.

### Progress by Dallas

By mid-1961, Dallas had acquired about half the necessary land for its pipeline. The 120-ft wide right of way has cost in fee about 63 cents per foot of right of way. The total length to be acquired is 169,770 ft; 81,514 ft have been acquired at an average cost of $175.30 per acre, the total number of acres involved in this 81,000 ft being about 295. Normally, the land in question has been selling for around $100 per acre, but in terms of agriculture, it is not worth this amount. The rush of urbanites to invest in tax loss property in the country has vastly inflated all rural property in the Dallas area. Taking these factors into consideration, the city considers the awards to date quite reasonable.

# Methods of Characterizing Missouri River Organic Materials of Taste and Odor Interest

*DeVere W. Ryckman, Nathan C. Burbank, and Edward Edgerley*

*A paper presented on Apr. 21, 1960, at the Kansas Section Meeting, Emporia, Kan., by DeVere W. Ryckman, Director, San. Eng. Research and Graduate Program; Nathan C. Burbank, Head, Civil Eng.; and Edward Edgerley, Asst. Prof., all of Washington Univ., St. Louis, Mo.*

FOR many years the Missouri River has provided a source from which potable water is produced for millions of people located in seven states. The lower Missouri River has long been known for its extremely heavy turbidity loads, which required water treatment facilities along the river to be especially concerned with the removal of high suspended-solids concentrations. With the closing of the Fort Randall and Gavin's Point dams in South Dakota in the early 1950's, the last of the impounding reservoirs in the upper Missouri River, the amount of suspended solids in the lower 900-mi section of the river was drastically reduced.[1]

The lower Missouri River (that portion of the river below the Fort Randall Dam) bounds five states and traverses the full width of the state of Missouri. This section of the river serves as a source of water for numerous centers of population in Missouri, Kansas, Nebraska, Iowa, and South Dakota. These areas have grown in population and industry, and as an inevitable corollary of growth have increased waste discharges to the river.

With the combination of decreasing turbidity and increasing pollution in the river, the water treatment plants along this section of the river have noticed an increase in the frequency of taste and odor problems, thus finding it more and more difficult to produce a water of acceptable taste and odor quality. The necessity of distributing a taste- and odor-free water and the large expenditures often involved in producing a water of acceptable quality are well known to everyone in the water industry. Industries that use water in plant operations such as plating, ion exchange processes, beverage production, and the manufacture of high-purity chemicals and allied products are also concerned about the presence of certain organic materials in their process water.

Thus the importance of the presence of taste- and odor-causing materials in the river was realized by representatives of industries and municipalities; this resulted in the formation of the Missouri River Pollution Monitoring Committee. This committee furnished materials of taste and odor significance for study in the sanitary engineering

laboratories of Washington University, St. Louis.

A study of these organic materials of taste and odor significance will be presented. Also, the techniques presently used to characterize these organic substances will be discussed.

## Mode of Study

The organic material studied was collected at various points along the lower Missouri River from Yankton, S.D., the first municipal water user below the last of the large impounding dams, to St. Louis, Mo., where the Missouri River discharges into the Mississippi. Along this 840-mi stretch of river, eight sampling stations were established at water treatment plants. Here activated-carbon filters were installed to monitor both raw river water and tap water. These sampling stations, shown in Fig. 1, were located at Yankton, S.D.; Omaha, Neb.; St. Joseph, Mo.; Kansas City, Mo.; Lexington, Mo.; Jefferson City, Mo.; St. Louis (Howard Bend), Mo.; and St. Louis County (North Plant), Mo.

Water was passed through the 127-cu in. carbon filter at a rate that allowed 5,000 gal of water to be filtered in a 2-week period. At the end of this period the carbon in the filter was replaced; the carbon containing the adsorbed organics was dried. The organic material was extracted with a suitable solvent. The solvent was then removed, leaving the concentrated organics. The weight of these was determined.

Chloroform was chosen as the solvent for three reasons: (1) other investigators[2] have shown that most taste- and odor-producing organics found in natural waters are chloroform soluble, (2) chloroform would eliminate groupings of organics that are not significant in taste and odor problems, and (3) chloroform-soluble organic materials obtained in preliminary studies confirmed the capture of odorous materials.

The concentrated carbon chloroform extract (CCE) was separated into groups using the principle of solubility partition.[2] This procedure, outlined in Fig. 2, divided the material into the following groups: ether insolubles, water solubles, amines, strong acids,


**Fig. 1. Sampling Stations**

*The Missouri River flows more than 800 mi between Yankton, S.D., and St. Louis County.*

weak acids, and neutrals. The group separation was accomplished by dissolving a tared sample of the original material in ether and filtering the mixture to remove the ether insolubles. The remaining solution was extracted with water and the water-soluble group recovered by evaporation. The remaining ether solution was extracted with 1*N* HCl, the water layer basified to above pH 10 and then extracted with ether to obtain the amines.

The ether solution containing the remainder of the organics following the

acid extraction was further extracted with 5 per cent $NaHCO_3$ solution. The resulting water layer was acidified to pH 2 with HCl and extracted with ether to separate the strong acid group on evaporation.

Again, the original ether solution was extracted with 1*N* NaOH. The resulting water layer was acidified to pH 2 with HCl and extracted with ether, obtaining the weak-acid group on evaporation of the ether. The neutrals were obtained by evaporating the remainder of the original ether solution.

A column-chromatographic separation procedure was used to separate the neutral group into three subgroups: aliphatics, aromatics, and oxygenated materials. As shown in Fig. 2, the neutrals were adsorbed on a column of silica gel, and the column elutriated first with isooctane, then with benzene, and finally with a 1:1 mixture of chloroform and methanol.

All groups and subgroups were carefully dried at a temperature of 55°–60°C with the aid of a jet of purified air. After desiccation, the weights of these materials were determined.

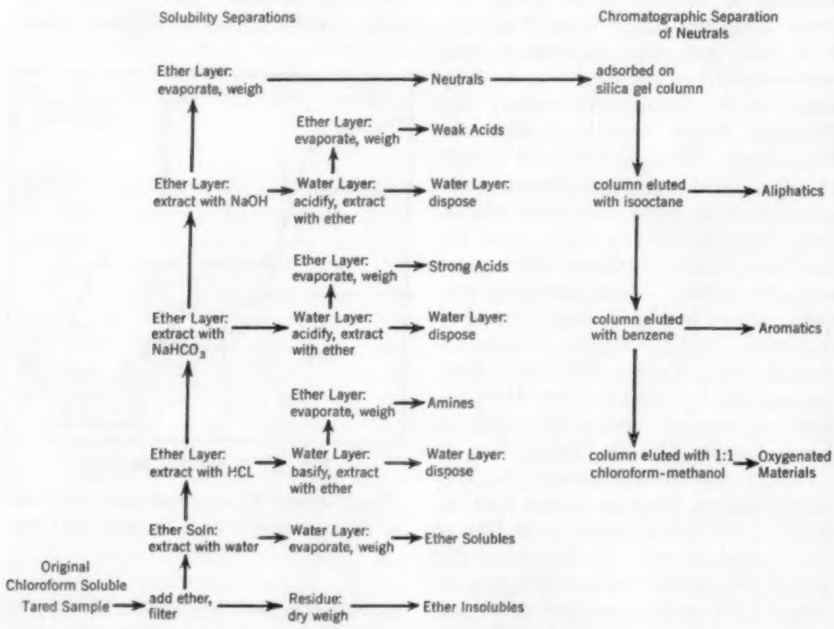


**Fig. 2. Group Separation of Organic Extracts**

*Various fractions of the CCE were separated by the methods charted.*

## Taste and Odor Characteristics

Because this study is predicated on the existence of taste and odor problems encountered with Missouri River

TABLE 1

*Average Quantity of CCE at Each Sampling Point—1958*

| Sampling Point | Organics *lb/day* |
|---|---|
| Yankton, S.D. | 4,100 |
| Omaha, Neb. | 4,900 |
| St. Joseph, Mo. | 3,900 |
| Kansas City, Mo. | 4,800 |
| Lexington, Mo. | 10,100 |
| Jefferson City, Mo. | 7,300 |
| St. Louis City (Howard Bend), Mo. | 17,200 |
| St. Louis County (North Plant), Mo. | 16,200 |

waters, it was necessary to select a parameter to measure this characteristic. The threshold odor test was used for this purpose as outlined in the tenth edition of *Standard Methods.*[3] It was determined through preliminary studies that the significant odor-producing materials were concentrated in the neutral- and weak-acid groups. Therefore, odor determinations were conducted on these two groups as well as on the total CCE. The same five-man odor test panel was used for all determinations.

The remarkable ability of natural waters to remove certain organics is well recognized. More recently, some

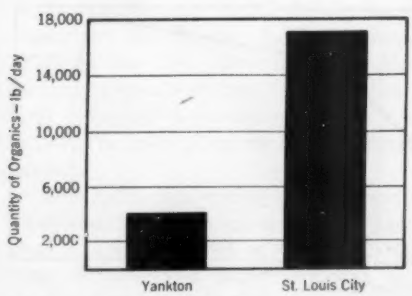


**Fig. 3. Average Quantity of Organics in the Missouri River—1958**

*The average amount of organics generally increases as the river flows downstream.*

organics have been found to be resistant to biologic degradation.[4, 5] This information led the authors to investigate the feasibility of using biologic extraction procedures as a method of: (1) further concentrating the organics that would be troublesome from the standpoint of their persistence, and (2) isolating those compounds that have considerable odor potential. In this investigation, biochemical studies were conducted on total CCE under simulated stream conditions.[6] Samples of

TABLE 2

*Average Concentration of CCE in Raw and Tap Waters at Each Sampling Point—1958*

| Sampling Point | CCE Concentration *ppb* | |
|---|---|---|
| | Raw Water | Tap Water |
| Yankton, S.D. | 37 | 39 |
| Omaha, Neb. | 36 | 47 |
| St. Joseph, Mo. | 33 | 38 |
| Kansas City, Mo. | 41 | 36 |
| Lexington, Mo. | 36 | 45 |
| Jefferson City, Mo. | 32 | 46 |
| St. Louis City (Howard Bend), Mo. | 41 | 48 |
| St. Louis County (North Plant), Mo. | 36 | 53 |

sufficient size for these studies were obtained by combining portions of the total extracts collected from time to time over several months. The two-bottle single-dilution technique for long-term BOD studies[7] was used to measure the degree and rate of degradation of these materials. The chemical oxygen demand[3] of the organics was determined before biological degradation and threshold odor levels were measured on the contents of the reaction vessels at the beginning and end of the 20-day testing period. Oxygen use was determined daily.

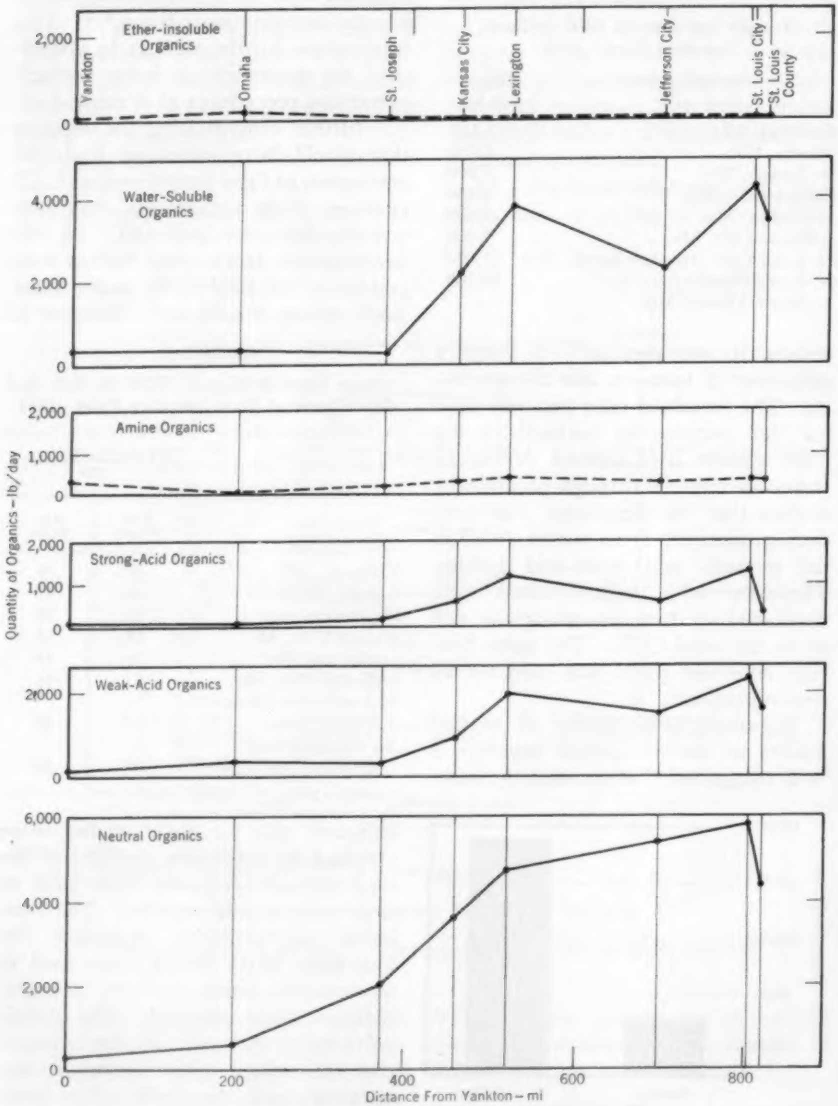


**Fig. 4. Quantity of Organics in the Groups Separated**

*The samples for these curves were collected Feb. 17–Mar. 3, 1958.*

Nitrite determinations were employed to insure that the results of oxygen use could be scribed only to the carbonaceous phase.

Infrared spectrographs were prepared of the original organics used in the BOD studies and of the CCE extracted from the BOD bottles at the end of the degradation period. Spectrographs were also prepared of total samples of organics from the various sampling stations and of the various group separations.

**Results and Discussion**

Data on the quantity of CCE passing each of the eight sampling stations have been continuously collected since October 1957. The results for 1958 are shown in Table 1. This information was obtained by continuously measuring the odorous organics contained in a portion of the river water at each sampling point. The weighted daily averages of organics were computed with flow data supplied by USGS. It may he observed that the average amount of organics generally increases as the river flows downstream. As Fig. 3 shows, 4,100 lb/day of CCE passed the Yankton sampling station while over 16,000 lb/day were measured at the St. Louis stations. This is the case notwithstanding the processes of adsorption, sedimentation, and biological assimilation, which are known to take place in these natural waters.

The 1958 data listing average concentrations of organics in tap and raw waters are presented in Table 2. It may be observed that there was an apparent increase in the concentration of organics measured in tap waters in comparison with those measured in the raw waters. This tends to demonstrate the ineffectiveness of presently used water treatment procedures in removing these substances. The increase of these organics during water treatment is a major problem, and is being further investigated.

Group separations were performed on selected sets of total organics. A set consisted of organics collected over the same 2-week period at each sampling station. Results of group separations on a set of samples collected between Feb. 17 and Mar. 5, 1958, are presented in Fig. 4 to illustrate the type of information gained through this method of analysis. It may be seen from these data that there is little significant difference in the quantity of the ether-insoluble group or the amine group between the various sampling stations. The quantity of neutrals and weak acids, however, significantly increases at sampling points downstream from Yankton. It is to be noted that the latter groups are the ones that have been related to the most odorous fractions of the total organics. There was also an appreciable increase in the water-soluble group at downstream sampling points, and some increase in the strong-acid group. Although these two groups in themselves do not contribute significantly to the odor content of the total organic extract, the concentration of these materials is of importance in correlating results with sources of organic materials entering the river.

The results of the column chromatography study of the neutral group for this same set of samples are illustrated in Fig. 5. It is to be noted that there was some increase in the aliphatic and aromatic portions, and a very significant increase in the oxygenated derivatives at downstream sampling stations. This is evidence that certain aliphatic and aromatic constitu-

ents are persisting in the river. The major increase in the oxygenated derivatives provides a basis for considering the possibility that the organics entering the river are, through partial degradation, being converted to materials in this group.

materials in the sample, as evidenced by the heavy carbonyl band at 5.9μ and the general absorption from 7.5 to 16μ, tend to obscure other materials that may be present. The separated fractions, particularly the aliphatic and aromatic fractions, show different charac-

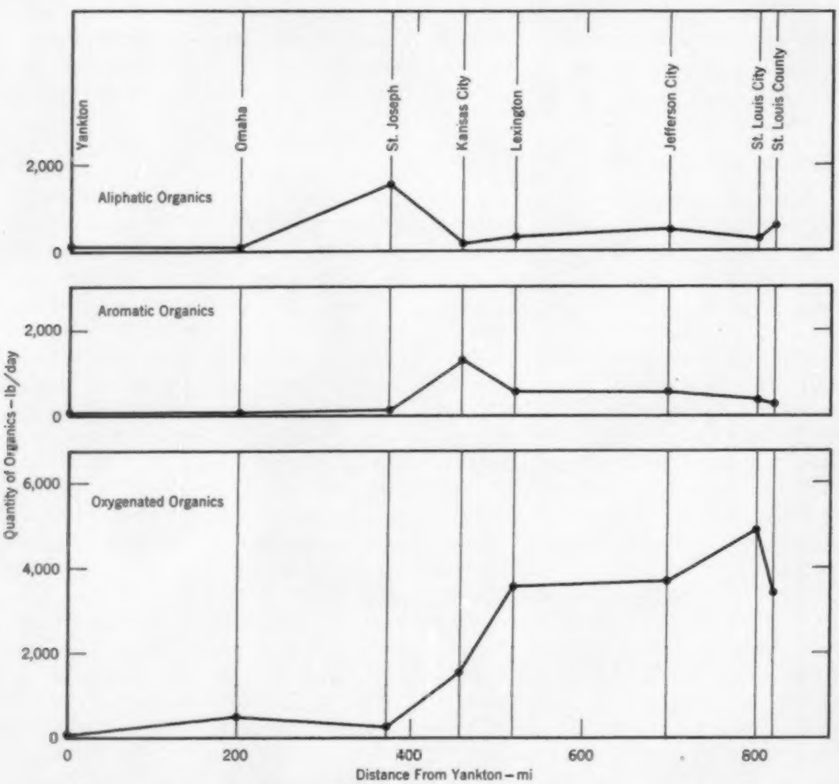


**Fig. 5. Quantity of Organics in the Chromatographic Separation Groups**

*The samples for these curves were collected Feb. 17–Mar. 3, 1958.*

The results of the infrared spectrographs prepared on the raw-water samples from various stations on the Missouri River were similar to the spectrographs shown in Fig. 6 for the St. Louis County sample. The oxidized

teristics, although specific chemicals are not revealed on these samples.

Results of threshold odor tests conducted on the set of samples used for the group separations described above are presented in Table 3. These data

include threshold odor results obtained on total and neutral fractions of the organic extracts from both raw and tap waters. The concentration of total organics required to produce a threshold odor generally decreased downstream from Yankton in both raw and tap water samples. This means that the odor potential of these organics actually increases at downstream sampling stations. It required 430 ppb of the total extract from the raw water at Omaha to produce an odor, but it took only 128 ppb to produce an odor from the St. Louis County (North Plant) organic sample collected during the same period. With organics from the tap water, it required 720 ppb for the Yankton sample to produce an odor, but one was obtained using only 256 ppb of the sample from St. Louis County (North Plant). In the latter case, there is almost a threefold increase in the odor potential of the organics at the downstream sampling point compared with that at the upstream point.

With the organic extract samples from raw water, there is some decrease in the concentration of the neutral-group organics required to produce a threshold odor at the Omaha upstream station in comparison with the concentration required at the St. Louis stations, as illustrated in Table 3. A greater difference may be observed for the neutral-group organics from the tap waters between the Yankton and St. Louis stations. The interpretation of this is that the odor potential of the neutral-fraction organics also increases at the downstream St. Louis stations; this was noted previously in connection with the total organic extracts.

The BOD study was conducted on portions of total extract combined from samples collected over the period from October 1957 to July 1958. Chemical oxygen demand values were measured on 10 mg of the total extract. BOD was obtained for a concentration of 5 ppm of the extracted organic material, this being a concentration that would be expected to provide an adequate measurable oxygen depletion for

TABLE 3

*Threshold Odor Results on Samples of Organic Extract* *

| Sampling Point | Threshold Odor—*ppb* | | | |
|---|---|---|---|---|
| | Raw Water | | Tap Water | |
| | Total Extract | Neutral Fraction | Total Extract | Neutral Fraction |
| Yankton, S.D. | | | 720 | 512 |
| Omaha, Neb. | 430 | 324 | 304 | 204 |
| St. Joseph, Mo. | 304 | 430 | 256 | 362 |
| Kansas City, Mo. | 218 | 430 | 304 | 512 |
| Lexington, Mo. | 256 | 362 | 362 | 362 |
| Jefferson City, Mo. | 180 | 92 | 151 | 92 |
| St. Louis City (Howard Bend), Mo. | 362 | 180 | 430 | 256 |
| St. Louis County (North Plant), Mo. | 128 | 180 | 256 | 256 |

* Samples collected Feb. 17–Mar. 5, 1958.

TABLE 4

*Results of BOD Study on Organic Extracts* *

| Sampling Point | BOD & COD of 5-ppm Solution of Organics | | 20-Day BOD Proportion of COD |
|---|---|---|---|
| | 20-Day BOD *ppm* | COD *ppm* | % |
| Yankton, S. D. | 0.76 | 10.70 | 7.2 |
| Omaha, Neb. | 0.75 | 10.75 | 7.0 |
| St. Joseph, Mo. | 1.37 | 11.00 | 12.4 |
| Kansas City, Mo. | 1.53 | 11.00 | 13.9 |
| Lexington, Mo. | 1.25 | 10.55 | 11.9 |
| Jefferson City, Mo. | 0.75 | 10.05 | 7.5 |
| St. Louis City (Howard Bend), Mo. | 0.75 | 11.75 | 6.4 |
| St. Louis County (North Plant), Mo. | 0.65 | 11.25 | 5.7 |

* Chloroform-soluble organics combined from samples collected over the period October 1957–July 1958.

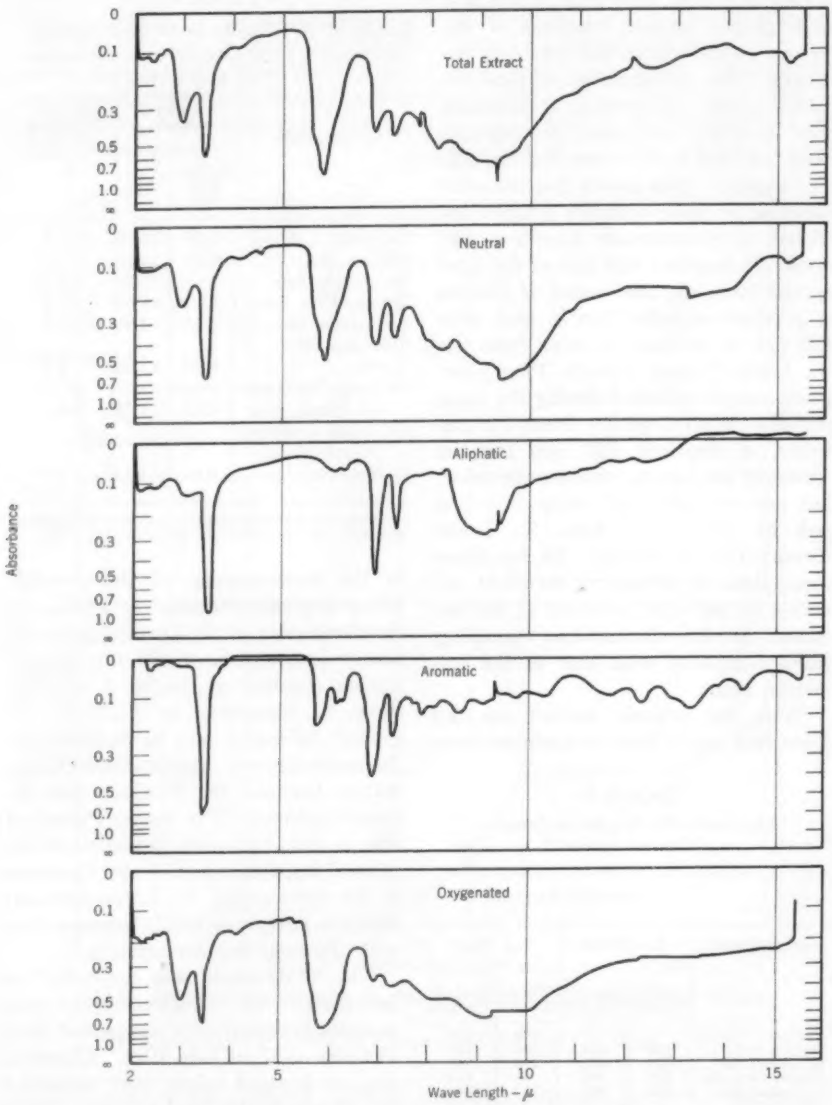


**Fig. 6. Spectrographs of Organic Extract From Raw Water**

*These infrared spectrographs were made from St. Louis County samples.*

degradable organics. The chemical oxygen demand of 5 mg of the organic material and the 20-day BOD values for 5 ppm of these organics for the various sampling stations are listed in Table 4. The 20-day BOD values computed as a percentage of the measured chemical oxygen demand are also given. These values are in the range of 5 to 14 per cent, which is very low compared to values of usually over 60 per cent for readily assimilated materials. As BOD values for organic materials that are known to be biologically resistant have been reported [4] to be less than 10 per cent of the chemical oxygen demand values, it may logically be concluded that these odorous organics are in this same resistant group.

The threshold odor levels measured on the contents of the BOD bottles before and after the 20-day incubation period were observed to be the same. Infrared spectrographs prepared from the extract prior to degradation and from the organic material recovered by extraction following the incubation period are shown in Fig. 7 for a typical station. In general, there was no noticeable change between the spectrographs. This is further evidence that these substances are resistant to decay.

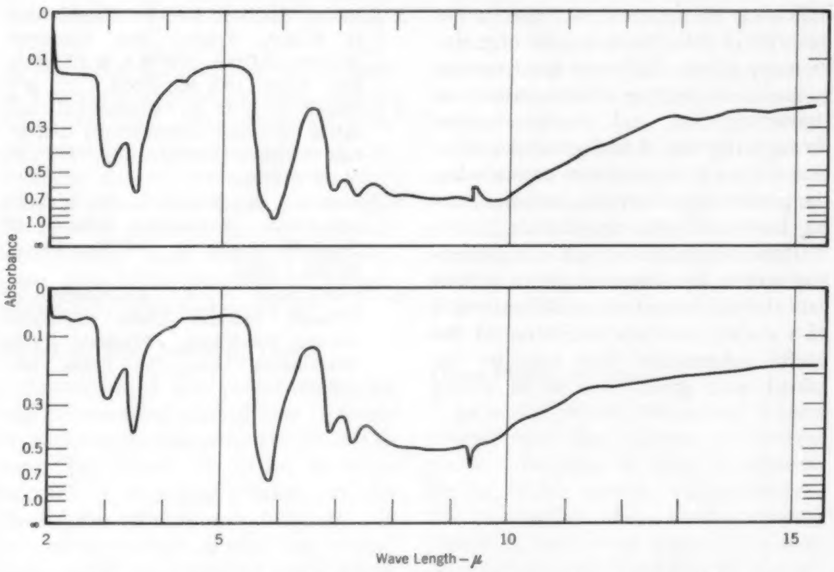


**Fig. 7. Spectrographs of Organic Extract Before and After BOD Study**

*Both spectrographs were made from St. Louis County samples. The upper curve represents the organics before the BOD study; the lower curve, after the study.*

## Summary

From the results of the work to date, it is indicated that the carbon filter is a good tool for the study of organics of taste and odor significance found in

the Missouri River. Threshold odor data is a most important parameter, and there is no substitute for this test. There is a buildup of organics in the Missouri River as it proceeds downstream, and these organics have higher odor potential than do those upstream. Water treatment is not removing significant quantities of organics of taste and odor significance and, in fact, is indicating an apparent increase in the quantity of chloroform-soluble organics in many cases. Infrared spectroscopy is useful in proving other methods of characterization, and characterization through the use of biological degradation studies is important in determining the persistence of organic material having taste and odor significance.

These results of the first comprehensive studies of odorous organics in both raw and tap waters on an 800-mi reach of a major river are indicative of the useful information that may be obtained with great promise in aiding both industrial and domestic water users.

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# Disinfection of a Distribution System After Disaster

Joe P. Teller

*A paper presented on Mar. 16, 1961, at the Texas Water and Sewage Works Short School, College Station, Tex., by Joe P. Teller, Regional Supervisor, State Dept. of Health, Sinton, Tex.*

NO city is immune to disaster. Floods, explosions, tornadoes, or hurricanes can strike any city without warning. Because disasters may come in any of several forms, plans to deal with them must be flexible. This article presents some of the problems arising from disasters and suggests some of the measures utility personnel may take to restore service.

## Flood at Port Lavaca, Texas

Examples of the problems arising and the solutions applied may be found in experiences following the Port Lavaca, Tex. flood. In 24 hr, 30 in. of rain fell on saturated ground, and the result was widespread flooding. It was severe enough to wash out several main water lines, plug up many sewer lines, and flood quite a few homes. Because of the speed of the washouts in the water distribution system, the system was completely exhausted of water by the time valves could be closed. The storm waters flowed into the broken mains, washed out fire plugs, and made many streets impassable. The severe rain caused the motors on the pumps in the well field to short out, and a fuse was blown on the electric supply line to the well field area. The two roads leading to the well fields were covered with at least 2 ft of water in some places, and early attempts to start standby equipment were stopped before they could really begin.

The hauling and distribution of water to the residents of Port Lavaca was a major undertaking in itself, involving 150 men and 20 pieces of equipment. The problems encountered in that operation are not concerned with disinfection, but would be of vital interest in a similar situation.

## Three-Phase Action

As stated above, the storm waters flowed into the system in several places. Because of this, disinfection of the entire system was necessary. To accomplish this, three separate phases of work were begun. As soon as water receded, the phase of line repair and the phase of getting water from the well field began. Because of the vital necessity of water, street personnel, volunteers, sewage treatment personnel, and water utility personnel were all pressed into service.

While work continued on a 24-hr basis on these two phases, the third was started. A chlorinator manufacturer was contacted, and a chlorinator capable of delivering 400 lb of chlorine per day was sent to Port Lavaca. This manufacturer also sent a technician to supervise installation, and the chlorinator was installed at a point in the sys-

tem so as to allow a 0.5-mil gal ground storage tank to serve as a contact chamber.

Meanwhile, the first two phases were nearing completion. Using one electric motor and one emergency gas engine, water was pumped into the ground storage tank, chlorinated to the extent of 200 ppm, and stored. This 0.5-mil gal supply was the first water available for fire-fighting purposes in over 36 hr. When sufficient pumps were in operation to insure 1 mgd from the wells, sections of the system were opened, and water with a chlorine residual of 200 ppm was introduced.

Before charging the system, handbills, radio, public address trucks, and all available means were used to advise the residents to close all taps and report any leaks to the water plant. These same media of communication were used to inform the people that a limited supply of water was available for flushing purposes. As had been expected, this water was used for every conceivable purpose at the rate of approximately 90,000 gpm.

Six crews toured the city for 12 hr, opening fire hydrants and flushing lines until a definite chlorine residual had penetrated into all points of the system. It must be noted that despite the massive dose of chlorine applied at the plant, in many places no residual was found for as long as 30 min of steady flushing. The lines were obviously in great need of disinfection. A chlorine residual of 150–200 ppm was maintained for 24 hr. During the last 12 hr, periodic stepdowns in the chlorine dosage rate were made until water at 1–10 ppm chlorine was entering the system. At the end of the 24-hr period, flushing was again practiced. The final flushing took place during the afternoon of the third day after the flood had occurred.

As before, radio, newspapers, and all means of communication were used to urge the residents to use the water for necessity only. It was explained that only a limited quantity of water was available, and would be turned on at 6 PM. Prior to this time, high school students made a door-to-door call in the city. At each house, the resident was advised to flush the house service line in two separate places for 5 min before using. Handbills were left at houses where no one was at home. Excellent cooperation from the radio and television stations enabled the entire city to know that only a limited supply of water was available, and that it should be used for necessities only. Actually, ample water was available for normal usage, and wells were producing at 1.25 mgd. In the 60-min period from 6 to 7 PM, water pressure dropped from 55 lb to 15 lb. Not until 11 PM did the water pressure rise above 40 psi. After that, only a massive clean-up job and repairing the numerous small line breaks remained to be done.

### Help for Residents

Most of the many inquiries made of the water department during this period were concerned with the disinfection of private wells. Several pint jars were obtained and filled with calcium hypochlorite. These were passed out to any person wanting them, with instructions on how to use them effectively.

Residents also wanted to know measures that could be taken to disinfect inundated homes. Flood waters leave a layer of foul-smelling mud and silt on floors and furniture. Quaternary ammonia has been found to be very effective in cleaning and disinfecting flooded homes and business houses.

### Preparedness Measures

Experience in Port Lavaca showed that of the many measures that could be taken in preparation, a few are generally applicable.

1. An up-to-date map of the distribution system, showing size of line, fire hydrants, and valve locations, should be available.

2. Adequate, well maintained, emergency power equipment should be on hand. Whether it is gasoline or diesel, if it doesn't work, it is worse than useless.

All valve locations should be clearly marked with distances from at least two relatively permanent structures, such as telephone poles, street lights, or curbs. A good system for a record of this nature consists of large cards with the type valve and associated material on one side and a sketch showing location and distances on the other side.

Besides taking these measures, a utility should have many pieces of equipment. A portable power source, a portable public address system, several hundred pounds of any substance with free chlorine available, and portable self-powered pumps are useful in disaster conditions.

### Conclusion

Finally, this advice may be given:

1. Never become complacent. Just because a disaster has never occurred in a city does not mean it never will occur. Do not let standby equipment become unworkable. Use it frequently; have it ready.

2. Men with public health responsibility for a city can never assume that the water is safe. The utility must insure that it is safe. Should the slightest possibility of contamination occur, disinfection is called for.

It is to the credit of the Port Lavaca water utility personnel, city and county officials, and those who helped restore the water service that despite known contamination of several sections of the system, there was not a single case of water-borne disease.

# Case History of Salt Water Encroachment Caused by a Storm Sewer in Miami

**Francis A. Kohout**

*A paper presented on May 16, 1960, at the Annual Conference, Bal Harbour, Fla., by Francis A. Kohout, Geologist, Ground Water Branch, US Geological Survey, Miami, Fla.*

IN the period between 1909 and 1930, drainage canals were constructed westward from the coast through the Miami area into the Everglades to reclaim low lying land for urban and agricultural use. These canals have been the primary cause of salt water encroachment in the Biscayne aquifer, which is a highly permeable limestone aquifer extending from land surface to an average depth of 100 ft below mean sea level. Parker [1] stated that the canals have induced encroachment of salt water in two ways:

1. They have served to drain off fresh water stored in the aquifer in the coastal zone.
2. They have acted during certain dry periods as inland extensions of the sea, carrying salty water inland for several miles and allowing it to leak out to contaminate the aquifer all along their course.

Maps showing the progressive movement of salt water from 1904 to 1959 (Fig. 1 and 2) demonstrate the influence of the drainage canals on salt water intrusion in the Biscayne aquifer. The maps are adapted from several reports by Parker,[1] Klein,[2] and Schroeder and others,[3] and are extended to 1959 in this report.

The canals were uncontrolled until 1939, and ineffectively controlled until 1946. Salt water was detected in several of the supply wells near the Miami water plant (Fig. 1) as a result of drought conditions in 1943–46. A dam with removable piles of sheet steel was installed in the Miami Canal at 36th Street in 1946 to replace a tidal gate that had proved ineffective under drought conditions. The shrinkage of the lobe of salt water that extended along the axis of the Miami Canal (Fig. 2) and the decrease in chloride content from more than 1,600 ppm in 1946 to 50 ppm in 1954 in Well G 199 (Fig. 3), give evidence of the beneficial effect of the control structure.

Salinity control dams in the Biscayne and Little River canals also were effective in moving the salt water front seaward along those canals. Because of local opposition, however, the control structures in the Tamiami Canal (1 mi west of Red Road) and the Coral Gables Canal (at Red Road) were placed too far upstream to be effective, and salt water continued its inland advance.

Two danger areas are apparent on the map for 1959. The protection afforded by the salinity control dam in the Miami Canal at 36th Street is being jeopardized by the movement of salt water northwestward from the Tamiami Canal toward a center of pumping in the Miami well field, located ap-

proximately at the bend in Red Road. The increase in pumpage from 60 to 80 mgd in the well field may be a contributing factor.

The other danger area is west of Arch Creek. Three factors—an ineffective salinity control in Arch Creek, the location of the control dam too far upstream in Biscayne Canal at 131st Street, and pumping in the North Miami well field—have combined to produce a significant inland extension of salt water between the Biscayne Canal and Arch Creek. Salt water now underlies part of the North Miami well field at a depth of about 50 ft (Fig. 2, 1959), and the use of some wells has been discontinued. These circumstances suggest that serious trouble from salt water contamination in the North Miami well field may occur in the near future.

## Contact Between Salt and Fresh Water

The contact between fresh and salt water in the Biscayne aquifer is not sharp. Salt water and fresh water mix to produce a significantly thick zone of diffusion in which the chloride content grades from about 16 ppm (fresh water) to about 19,000 ppm (sea water). In Fig. 4, the zone of diffusion is represented by isochlors that pass through points of equal chloride content, as determined by the altitudes and chloride contents of water samples from many wells. An isochlor, of course, has horizontal dimension; in Fig. 5 the geographic distribution of salt water is represented by altitude contours on the 1,000-ppm isochlor surface.

## Modification of a Storm Sewer

In August 1954, the state road department began installing a storm sewer beneath the road grade of 27th Avenue as part of the widening of 27th Avenue and US Highway 1 to four lanes (Fig. 5). A vertical-sided ditch was cut into the solution-riddled limestone of the Biscayne aquifer. The conduit for the discharge of storm water was formed by covering the lower 6 ft of the ditch with a concrete slab and backfilling the remainder of the excavated hole up to road grade (Fig. 6). The storm sewer, in reality, was an uncontrolled drainage canal because its bottom ranged from 3 ft below mean sea level at the shoreline to sea level at a distance of 9,000 ft from the shore.

The possible detrimental effects of the drainage system were called to the attention of officials of the Dade County Water Control Office and the Miami Department of Water and Sewers. Plans were formulated for the construction of a salinity control dam made of sheet steel piles at the outlet of the storm sewer to Biscayne Bay. Two years passed before the dam was installed. As data in the Silver Bluff area were available for a period prior to the construction of the canal, the time lapse provided an excellent opportunity for observing the movement of salt water in the aquifer under uncontrolled drainage conditions and later under controlled conditions. This article presents these observations by a series of water table and isochlor contour maps.

Several canals in addition to the 27th Avenue Canal were excavated during the highway construction:

1. A spur canal extending about 1 mi westward from 27th Avenue beneath US Highway 1

2. An outlet canal beneath 22nd Avenue from Biscayne Bay north to US Highway 1

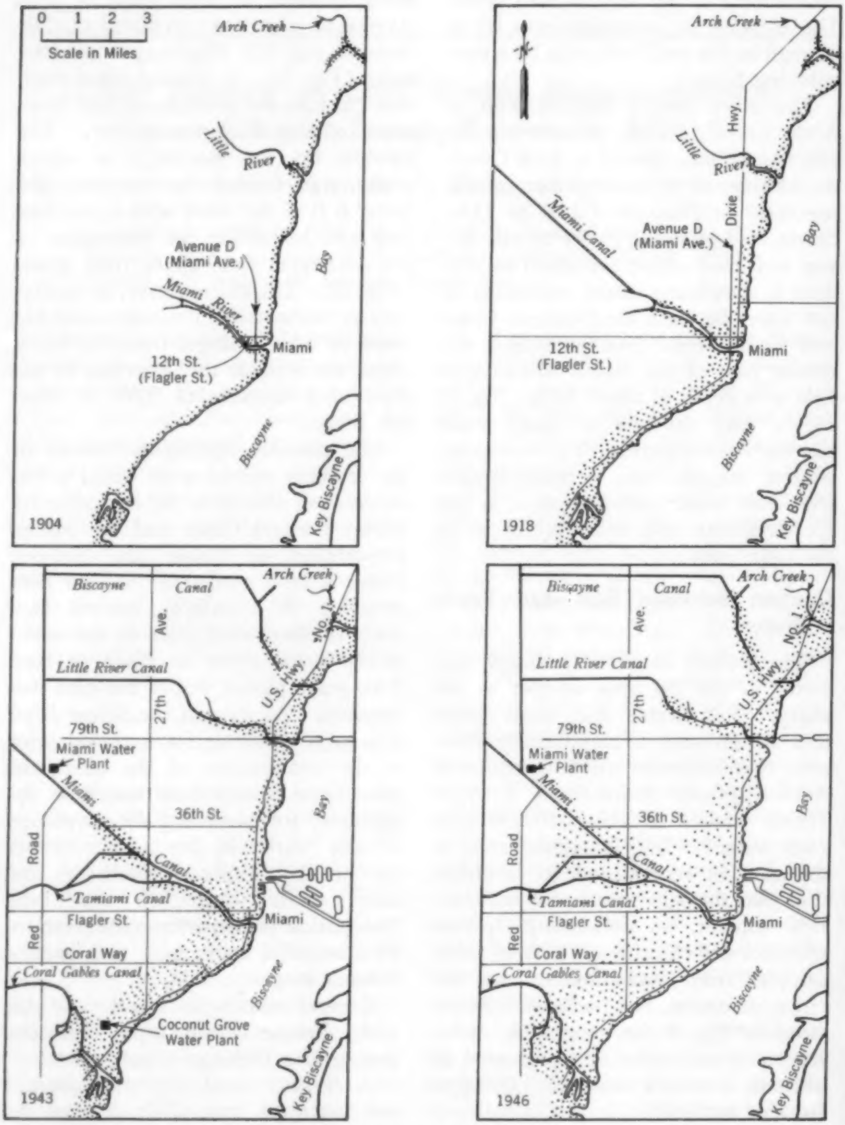


**Fig. 1. Encroachment of Salt Water in the Biscayne Aquifer, 1904–46**

*Shaded areas show extent of salt water encroachment.*

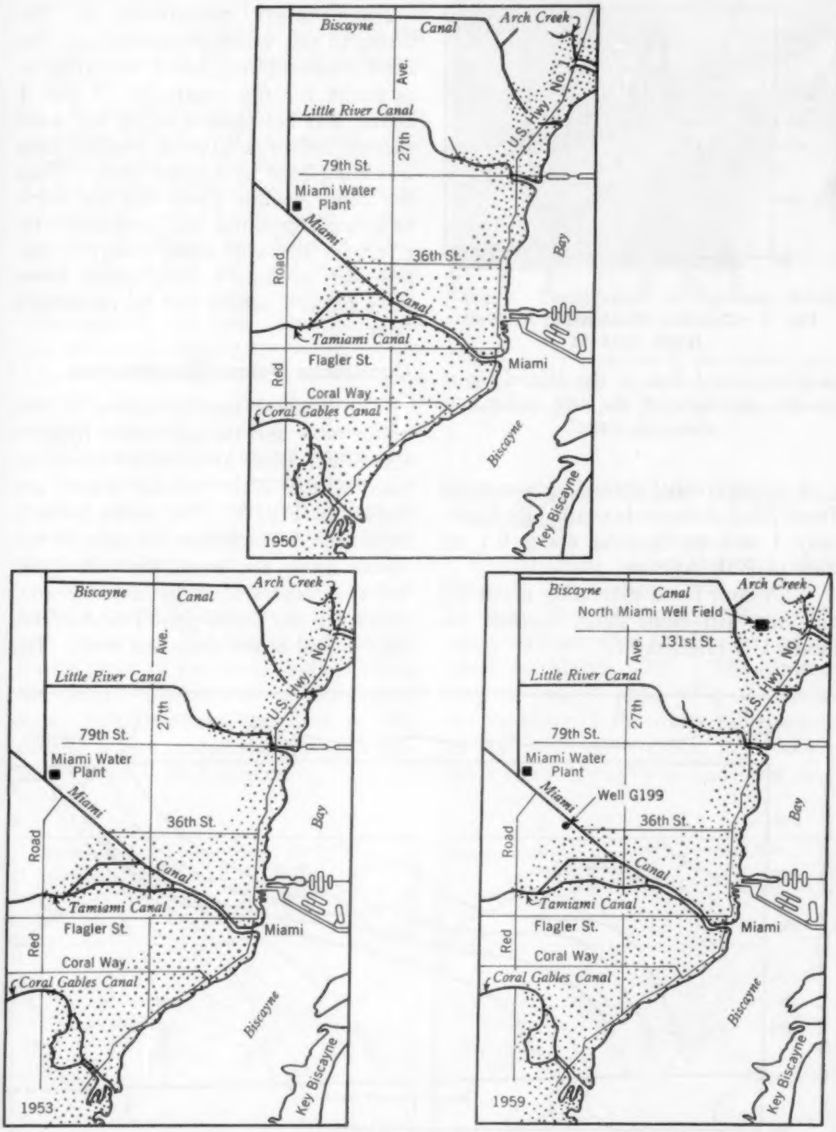


**Fig. 2. Encroachment of Salt Water in Biscayne Aquifer, 1950–59**

*Control measures on Miami Canal reduced chloride content in Well G199 from 1,600 ppm in 1946 to 50 ppm in 1954.*

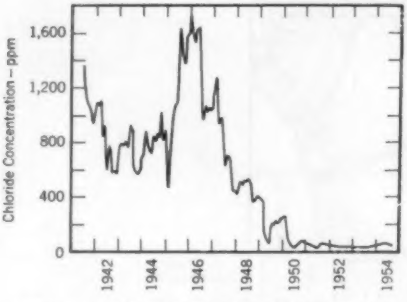


**Fig. 3. Chloride Fluctuation in Well G199, 1941–54**

*A new control dam in the Miami Canal caused shrinkage of the salt water lobe along the canal.*

3. A spur canal extending westward from 22nd Avenue beneath US Highway 1 and terminating about 0.1 mi east of 27th Avenue

4. A spur canal extending about 0.5 mi eastward from 22nd Avenue beneath US Highway 1.

After timely recognition of the threat of salt water contamination, the 22nd Avenue Canal, which was to serve as outlet for the canals No. 3 and 4 above, was not opened to the bay until shortly before a salinity control dam was completed in August 1956. Thus the 22nd Avenue Canal did not work as a drainage canal and produced little effect on the salt water front; it did, however, produce a complicated water table pattern, which will be mentioned later.

## Conditions Before Construction

The general configurations of the water table and the salt water front in the Silver Bluff area before construction of the 27th Avenue Canal are shown in Fig. 5. The water table is represented by altitude contours in feet above mean sea level; the salt water front is represented by altitude contours on the 1,000-ppm isochlor surface in feet below mean sea level. The

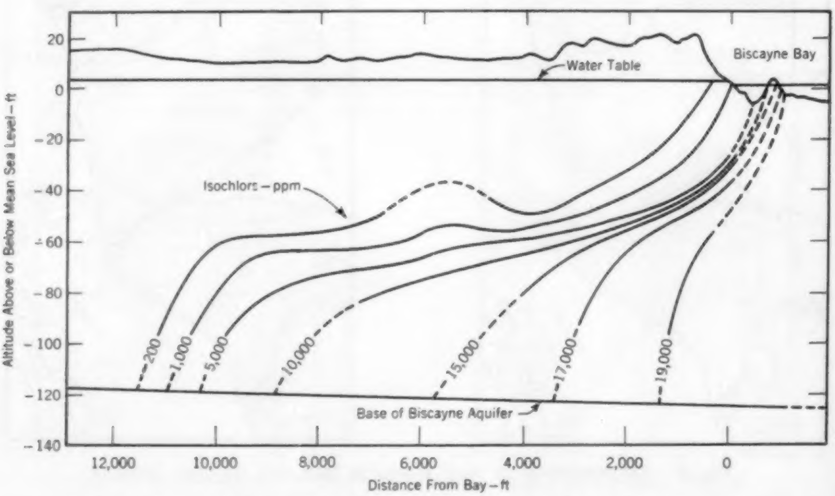


**Fig. 4. Zone of Diffusion in Biscayne Aquifer—Cross Section Through Silver Bluff Area, Nov. 2, 1954**

*Isochlors pass through points of equal chloride content.*

relation of the 1,000-ppm isochlor to other isochlor surfaces is shown in the cross section of the zone of diffusion (Fig. 4).

The inland sweep of the water table contours (Fig. 5, left) along the Coral Gables Canal and the Miami-Tamiami Canal system is produced by drainage of ground water into these canals. Control structures are dams of sheet-steel piles driven into the rock, with provision for removing alternate piles. The controls are open (alternate piles are removed) during the rainy season (June to November) and closed during the dry season, except during abnormal conditions. The water table quickly responds to control operations, so that contours will terminate at the control structures when the dam is closed, but will extend upstream when the dam is open.

Contours on the 1,000-ppm isochlor surface swing inland along the drainage reaches of the canals because the lowest point of the water table is along the canals. Dense salt water intrudes most rapidly along the axis of the canals, where counterbalancing fresh-water head is at a minimum.

**Fig. 6. Construction of Drainage Ditch Beneath 27th Avenue**

*Water surface shown is the water table. Unless impeded by a dam, this fresh ground water will flow to waste in the ocean.*

## Encroachment During Uncontrolled Drainage

Construction of the drainage canal beneath 27th Avenue was started at Biscayne Bay in August 1954. The canal was extended northward and finished in March 1955. The contour map of Jan. 3, 1955 (Fig. 7) shows the lowering of the water table caused by the incomplete drain. As only a short reach of the canal had been com-

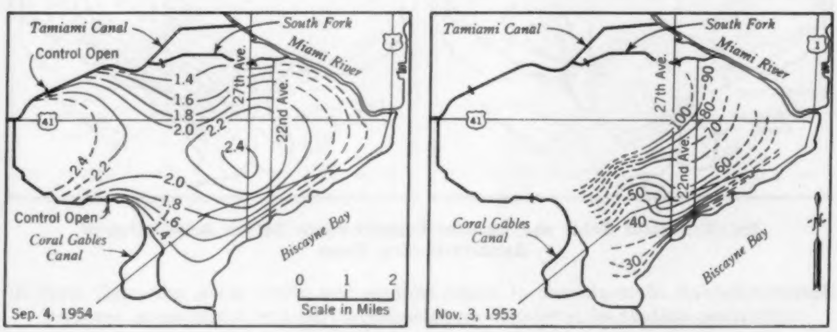


**Fig. 5. Water Table and Isochlor Contour Maps in Silver Bluff Area**

*Map at left shows altitude of water table in feet above mean sea level; map at right shows altitude of 1,000-ppm isochlor surface in feet below mean sea level.*

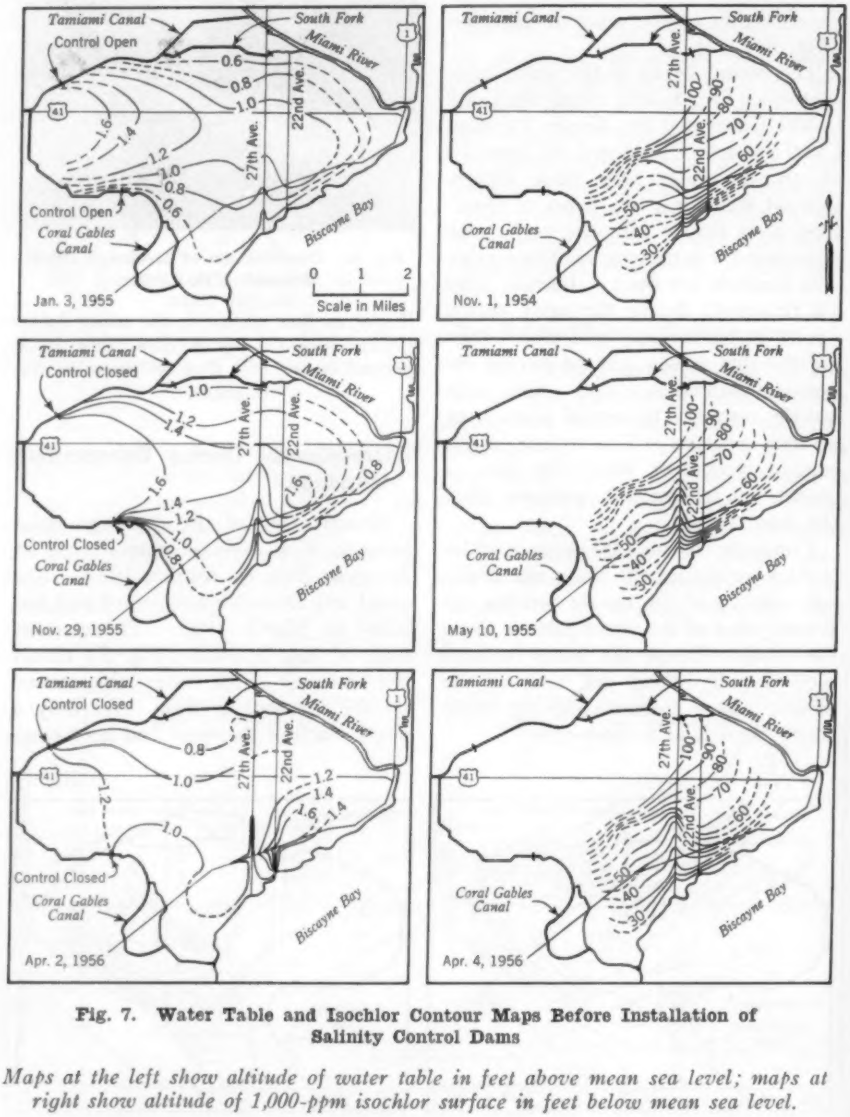


**Fig. 7. Water Table and Isochlor Contour Maps Before Installation of Salinity Control Dams**

*Maps at the left show altitude of water table in feet above mean sea level; maps at right show altitude of 1,000-ppm isochlor surface in feet below mean sea level.*

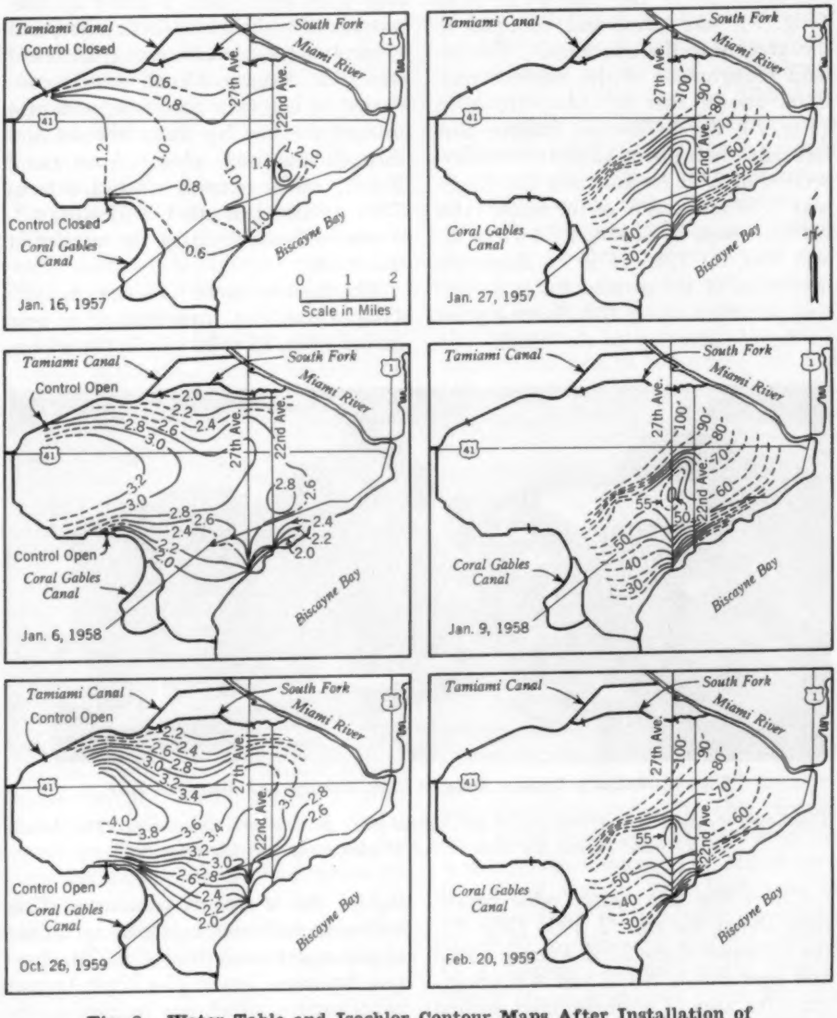


**Fig. 8. Water Table and Isochlor Contour Maps After Installation of Salinity Control Dams**

*Maps at left show altitude of water table in feet above mean sea level; maps at right show altitude of 1,000-ppm isochlor surface in feet below mean sea level.*

pleted by Nov. 1, 1954, the effect of the drainage on the salt water front (Fig. 7) was small and confined to the area near the shoreline. The inland realignment of the isochlor contours shows that by May 10, 1955 (Fig. 7), the 1,000-ppm isochlor surface had risen about 15 ft at the intersection of 27th Avenue and US Highway 1. Comparison of the water table contour maps of Sep. 4, 1954 (Fig. 5) and Nov. 29, 1955 (Fig. 7) shows the dissection of the ground water mound that prevailed along 27th Avenue prior to the construction of the canal.

Under the low water table conditions shown for Apr. 2, 1956 (Fig. 7), the influence of the 22nd Avenue Canal and spur canals No. 3 and 4 is apparent. An area of normally high ground water levels east of 22nd Avenue and north of US Highway 1 was tapped by canal No. 4, producing relatively high head along 22nd Avenue outlet canal and spur canal No. 3. Because of an unexcavated rock plug 100 ft wide near the bay, the canal system was not open to the bay on Apr. 2, 1956. Thus the 22nd Avenue Canal and spur canal No. 3 acted as line sources of recharge to the aquifer, and ground water flowed westward toward the 27th Avenue Canal, which continued to act as a line sink, and also toward the bay by paths around and through the rock plug. Spur canal No. 1, which extends westward from 27th Avenue beneath US Highway 1, was effectively draining the aquifer at this time.

The isochlor pattern of Apr. 4, 1956 (Fig. 7) differs from that of a year earlier (Fig. 7) primarily in the widening of the V-shaped contours. This widening indicates a lateral spreading of salt water away from the 27th Avenue drainage canal. The 22nd Avenue canal system, which was recharging the aquifer, had not been in existence long enough to produce a mappable effect on the salt water front.

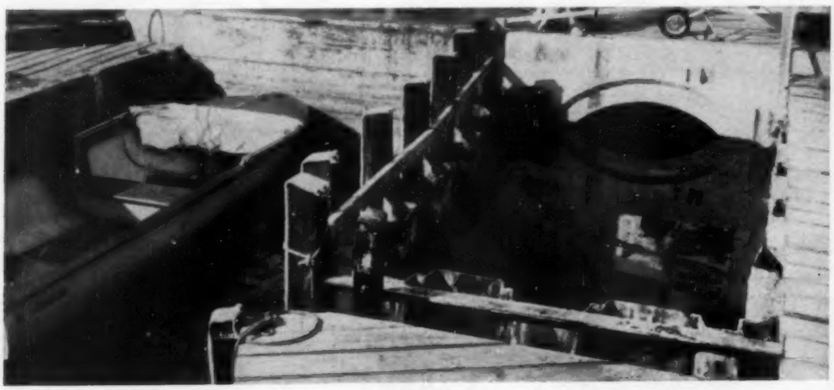

**Fig. 9. Salinity Control Dam at 27th Avenue and Biscayne Bay**

*The box-type dam is constructed of sheet steel piles driven into limestone. The fresh-water head inside the dam is 2.4 ft above the outside bay level.*

## Expulsion of Salt Water After Installation of Dams

The water table and isochlor maps of Fig. 8 show the changes in the hy-

drologic situation after salinity control dams were installed in August 1956 at the intersections of 27th Avenue and 22nd Avenue with Biscayne Bay. The dams were so constructed that their crests were approximately 2.8 ft above mean sea level (Fig. 9). The practical design of the dams fulfills several purposes: (1) the long overflow crest of the box-type dam permits the rapid discharge of large volumes of water collected from the highway surface during heavy rainfall, thus preventing damage to the roadbed; (2) salt water is prevented from moving directly upstream in the canal during reverse tidal flow; (3) the established crest prevents waste of fresh ground water; and (4) the relatively high fresh-water head maintained near the bay locally depresses the salt water front to depths not possible even before the canal was cut.

The effect of installing the 27th Avenue control dam is clearly demonstrated in maps of the water table (Fig. 8). Even at the extremly low stage of Jan. 16, 1957 (Fig. 8), a fresh-water head of slightly more than 1 ft above mean sea level was maintained in the canal system. Although the contour pattern along the spur canal described in number 1 is the same as it was during drainage, this segment of the canal system recharges the aquifer when the salinity control is in place. Along 27th Avenue midway between US Highways 1 and 41, in the water table maps of Jan. 6, 1958 and Oct. 26, 1959 (Fig. 8), ground water under relatively high head drains into the 27th Avenue Canal, flows southward under low gradients, and recharges the aquifer in the vicinity of US Highway 1, where relatively low head of the ground water prevails. Thus the canal acts as a drainage canal in the upstream reach and as a recharge canal in the downstream reach.

This redistribution of ground water head by the canal produced an unpredicted effect on the salt water front. In January 1957, when the 27th Avenue control was installed 5 months, a noticeable bifurcation of the salt water tongue developed near the intersection of 27th Avenue and US Highway 1 (Fig. 8). Seaward of the intersection, the high heads of fresh water rapidly depressed the 1,000-ppm isochlor, shown by the downstream-pointed V in the contours. Inland from the intersection, the lobe of salt water that had intruded during drainage was almost stagnant, having a slight tendency to be pushed eastward by fresh water moving toward the canal from the west. In the isochlor map of Jan. 9, 1958 (Fig. 8), the dissected lobe was sufficiently distinct to be mapped as a salt-water mound. In the map of Feb. 20, 1959 (Fig. 8), the mound was gradually being dissipated by dispersion of the salts and flushing.

## Summary and Conclusions

In many areas where pumping is the primary cause, salt water encroachment takes on the aspect of an irreversible onslaught of trouble, for in most cases pumping continues until the water becomes salty. The Miami area is blessed with a very high rate of recharge from rainfall, which averages about 60 in. per year, and this results in a bountiful ground water supply. These blessings do not mean that the water resources of the area cannot be jeopardized by unwitting development. With proper control, however, the problem of salt water encroachment can be solved, as this article has reported.

Leopold [4] has stated:

> America is now entering a period in which management rather than water

development will be the major engineering task. . . . Management . . . requires foresight in identifying both possibilities and difficulties, and initiation of investigations of ways to overcome the difficulties.

Appraisal, from the standpoint of management, is not merely the collection of records. To record history is neither appraisal nor management. Records are used to evaluate the characteristics of the resource. The function of management is to project these characteristics into the future, forecast the results of alternative actions, and develop plans utilizing these forecasted results to attain desirable results.

A completely adequate system of storm sewers for highways had been designed. That a damaging effect on fresh-water supplies would result from the system was not recognized until construction was underway. The cooperation of state, county, and city engineering departments, however, provided a solution that fulfilled the primary objective of the storm sewer without significantly damaging valuable water resources. No one is better equipped to protect these resources than the local water control engineer or the superintendent of the municipal water system. The final outcome of this case history is not completely known. It is clear, however, that the active interest and acceptance of responsibility of the several parties concerned helped overcome the difficulties. This case history may be considered an example of good water management.

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# Unusual Cases of Copper Corrosion

George B. Hatch

*A paper presented on Jun. 16, 1960, at the Pennsylvania Section Meeting, Pittsburgh, Pa., by George B. Hatch, Corrosion Research Group Leader, Calgon Co. (Div. of Hagan Chemicals & Controls), Pittsburgh, Pa.*

THE consumer generally feels that copper tubing should last a lifetime, and usually he is not disappointed. But in those rare instances when pitting occurs in copper tubing, holes may be formed after approximately a year of operation.

Copper, like other metals used for potable-water tubing, can be damaged from both general and localized corrosion. General corrosion of copper tubing in water service produces harmful side effects but seldom causes an appreciable decrease in the life of the tubing. Further, general corrosion usually can be controlled rather simply by treating the water. Localized corrosion markedly decreases the life of tubing. Most problems of copper pitting still remain to be solved by the corrosion investigator, but some puzzling instances of pitting encountered by the author may be of interest.

## Normal Film Formation

A thin film of cuprous oxide normally forms on copper surfaces exposed to potable waters. This oxide film generally is very fine grained, tightly adherent, and quite highly protective. It frequently is overlain by thin deposits of basic cupric salts that often enhance the protection.

The cuprous ion is rather unstable and readily oxidized. Hence, only the quite insoluble cuprous compounds or the rather tightly bound cuprous complexes are found in appreciable amounts. Cuprous oxide, as a result of its insolubility, generally forms next to the metal surface. In addition, metallic copper will reduce cupric ion to the cuprous form. Cuprous chloride also is only sparingly soluble and may form as a corrosion product. It has been reported to undermine the oxide on occasion and lead to disruption of the protective film.[1]

The cupric compounds generally found over the cuprous oxide film are basic carbonates, basic sulfates, or basic chlorides. Which of these basic salts will be found depends to a considerable extent on the relative concentrations of the particular anions in the water. Occasionally cupric oxide also will be found over the cuprous oxide film. Equilibria in the copper–cuprous ion–cupric ion system are complicated by the rather large number of complexes formed by both the mono- and divalent forms.

## General Corrosion

General corrosion of copper usually proceeds at too slow a rate in potable waters to affect appreciably the life of the tubing. Corrosion products, generally basic cupric salts, may slowly build up on the tube surface, but rarely

to such an extent as to cause trouble. The corrosion products also may dissolve in the water and cause a number of secondary problems. Perhaps the most obvious of these problems is the green or blue staining of washbowls and bathtubs.

A somewhat less obvious problem resulting from dissolved copper is its accelerative action on the corrosion of the more anodic metals that water may contact. Dissolved copper can deposit on iron and steel and markedly accelerate their corrosion. Although this can constitute a serious problem in recirculating systems, sufficient deposition to cause trouble seldom occurs in once-through domestic service. But zinc (in galvanized steel, for example) and aluminum are markedly more sus-

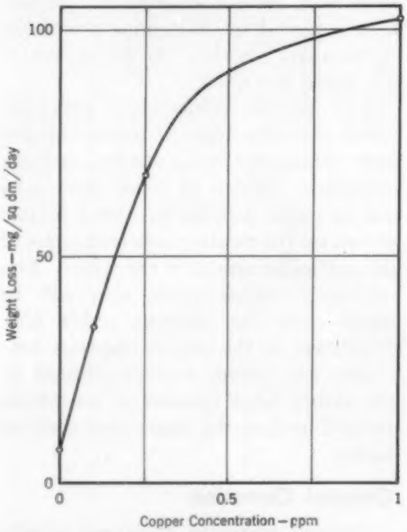


**Fig. 1. Influence of Dissolved Copper on Zinc Corrosion**

*A concentration of 0.1 ppm copper caused roughly a fivefold increase in the corrosion rate.*

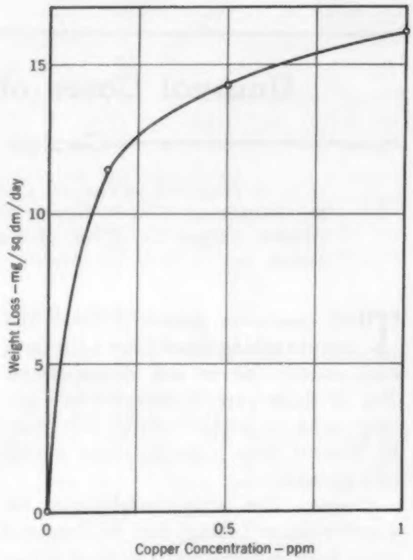


**Fig. 2. Influence of Dissolved Copper on Aluminum Corrosion**

*The corrosion of aluminum induced by copper was even more highly localized than that of zinc.*

ceptible than steel to the deleterious action of dissolved copper. The extreme susceptibility of zinc and aluminum to traces of dissolved copper has been mentioned in the literature often but ignored in practice too frequently; hence it can stand reiteration here.

Figure 1 shows the influence of dissolved copper on the corrosion of zinc by Pittsburgh tap water.* A concentration of 0.1 ppm copper caused roughly a fivefold increase in the corrosion rate. Further, it caused a localization of attack and marked pitting.

* These data were the results of small-volume (1 liter), agitated batch tests of the type described previously.[2] The tests were conducted at 35.0°C and pH 6.5, and lasted 5 days.

Figure 2 shows similar data for aluminum.* The accelerated attack on the aluminum caused by the dissolved copper was even more highly localized than the attack on zinc.

Elevation of the pH of the water to 6.8 or 7 generally suffices to reduce copper pickup to a very low level. There are, however, occasional exceptions where more extensive pH elevation is required. Glassy phosphates occasionally have been used to avoid additional pH elevation in the control of copper pickup. For example, an East Coast municipal supply of soft water continued to cause copper staining after the pH had been raised to 7. This was stopped by the subsequent addition of a sodium-phosphate glass,† although it had been added primarily for control of ferrous corrosion. It is perhaps of interest to note that this phosphate glass exerts some inhibitive action on copper pickup where the corrosion products are basic cupric chlorides, but not where they are basic sulfates.

Although a rare occurrence, the buildup of corrosion products produced by an essentially general attack of copper can proceed to such an extent as to cause trouble. Such a problem was experienced in several copper tubing lead-ins and domestic lines of a system with a soft, low-pH supply. Water analysis showed: total hardness (as $CaCO_3$), 14 ppm; total alkalinity (as $CaCO_3$), 13 ppm; chloride concentration, 10 ppm; and pH, 6.25.

The system was treated with a sodium-zinc phosphate glass ‡ to control ferrous corrosion. The appearance of a section of one of these domestic copper lines is shown in Fig. 3 (left). The bulk of the deposit—that is, the light material in the figure—is a copper phosphate that is in itself unique. It was not expected, particularly as a 6-month test at the filtration plant had shown no trace of deposit in copper lines. Apparently the low concentration of other anions renders this the least soluble form. The black streaks appear to be cupric oxide. The cuprous oxide present is rather coarse and from its physical appearance would not be expected to provide a very protective film. Figure 3 (right) shows the appearance of the line after pickling. The attack is essentially general, although there is a streak of the metal that has not suffered appreciable attack.

The lines became plugged in a few isolated instances, but most of the copper tubing, including adjacent lead-ins, was not affected. Such isolated attack in a system is unusual where essentially general corrosion of copper is involved. Isolated attack is more characteristic of pitting.

The problem recently was complicated by the detection of direct-current voltages of about 1 v, with occasional surges of 10 v between the house piping and one of the plugged lead-ins. The pertinence of this observation, however, seems quite questionable. There appears to be no logical reason for the current to jump back and forth between the high-conductance pipe and the very high-resistance water. In the absence of such a flow of current from the pipe to the water, and vice versa, no effect on the corrosion normally would be expected. Thus, the cause for the attack remains obscure.

* Type 3003-H14.

† Calgon, made by Calgon Co., Pittsburgh, Pa.

‡ Calgon TG.

## Impingement Attack

Impingement attack formerly seemed to be more or less confined to tubing in the marine and industrial fields, particularly to condenser service with sea water or brackish supplies. During recent years, impingement often has occurred with municipal supplies. This apparently has resulted from the use of existing facilities for expanded operations, together with a tendency to underestimate the sizes of tubing required for new installations.

Impingement results from excessive flow velocities. The rippled appearance of the metal in the affected areas seems to suggest solely mechanical action, but the deterioration actually is of an electrochemical nature. The high flow velocities interfere with the normal protective-film formation; consequently the attack proceeds at an abnormal rate. The generally high resistance of copper to most forms of corrosion does not include resistance to impingement. In this respect, copper is one of the least resistant of the metals commonly employed for water service. The flow velocity that can be tolerated by copper tubing without danger of impingement is somewhat dependent on the type of water handled. Apparently it is influenced by the speed with which the protective film can be formed and repaired. From a practical point of view, flow velocity generally should be no greater than 5 fps for most municipal waters. The flow velocity that can be tolerated is markedly reduced when entrained air bubbles or suspended solids become involved.

It perhaps should be emphasized that the preceding statements on impingement apply to copper rather than to its alloys. Many of the alloys show markedly greater resistance to impingement attack than does copper itself. As a result, the alloys generally are

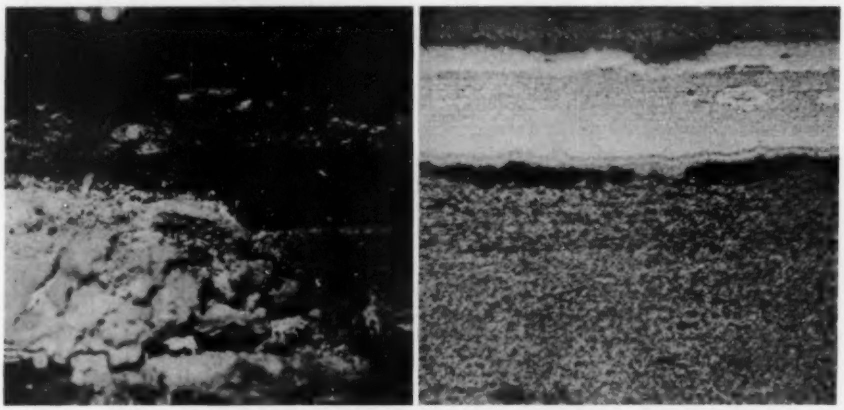

**Fig. 3. Appearance of Domestic Copper Lead-In Plugged With Corrosion Products and After Pickling**

*The photograph at the left shows the lead-in plugged with corrosion products. The light material is a copper phosphate deposit. The photograph at the right shows the appearance of the line after pickling.*

used for industrial service where rather high flow velocities may be anticipated.

Impingement pits generally are undercut on their downstream ends. Often the pits are horseshoe shaped. Occasionally, the affected surface presents a rippled appearance without definite undercutting on the downstream end. When active impingement is in progress, the affected areas remain essentially free of deposits.

The appearance of a copper lead-in line affected by a severe and widespread impingement attack in a hard bicarbonate well water (pH 7.3) is shown in Fig. 4. This line (1.5 in.) served a motel where operations apparently had exceeded expectations to a considerable degree. The undercutting on the downstream side (the upper side in Fig. 4) was so extensive that the tube surface had the feel of a rasp. The entire tube surface was covered with closely spaced impingement pits. Such widespread attack is rather unusual. It might be noted that the downstream ends of the pits where the attack had proceeded most rapidly were essentially clean. Light deposits were present on the unpitted areas and on the upstream ends of the pits.

Figure 5 (left) shows impingement in an air cooler that handled water from an industrial well supply of rather poor quality. Water analysis showed: total hardness (as $CaCO_3$), 1,450 ppm; total alkalinity (as $CaCO_3$), 172 ppm; chloride concentration, 820 ppm; sulfate concentration, 850 ppm; and pH, 7.2. Most of the affected area is rather uniformly thinned; in fact, the failures encountered resulted from excessive thinning. The protrusions resembling tubercles have an outer coating of iron oxide and an underlying layer of malachite (basic cupric carbonate). By far, however, the major portion of these protrusions consists of metallic copper, as shown in Fig. 5 (right) by the appearance of the tube after pickling.

The presence of iron oxide and corrosion products on the copper protrusions does not appear to indicate that particularly severe mechanical action had occurred. The manner in which the protrusions survived the impingement is rather puzzling. It looks as though the iron deposits and corrosion products had shielded the protrusions from the impingement.

**Fig. 4. Impingement Attack on Copper Lead-In**

*Such an impingement attack was unusually widespread.*

Severe impingement attack of copper tubing was found in the recirculating hot-water system of a hospital using a municipal supply with these characteristics: total hardness (as $CaCO_3$), 80 ppm; total alkalinity (as $CaCO_3$), 66 ppm; sulfate concentration, 12 ppm; chloride concentration, 5 ppm; and pH, 7.5. The water temperatures were maintained in the range

140–160°F. The appearance of a pickled section of copper tubing from the system is shown in Fig. 6 (right).

The pits show marked undercutting on the downstream side (the right side in Fig. 6) and a rather unusual elongation at right angles to the direction of flow. Excessive flow velocities were maintained, and a similar attack on the copper occurred throughout the system. Numerous replacements have been necessitated; and from the appearance of the sections examined, it seems only a matter of time before all the lines will have to be replaced. Even the bronze tube fittings, which are considerably more resistant to impingement than is copper, were similarly attacked, though the attack was less severe.

Impingement in recirculating hot-water lines often is localized in the portions of the system near the suction side of the circulating pump. In such instances, air that separates from the water as a result of pressure reduction, or air pulled into the lines through leaky faucets, seems to be responsible for the localization of the attack in this particular portion of the system.

The recirculating hot-water system of the hospital mentioned before also contained some steel, the corrosion of which caused red-water troubles. In January 1960, a sodium-zinc phosphate glass was applied to the system in a 5-ppm concentration to protect the steel. A section of copper tubing, before pickling, removed from the system several months later is shown in Fig. 6 (left). The pits contain light deposits and show no bright, bare copper areas. The impingement appears to be no longer active. The glassy phosphates

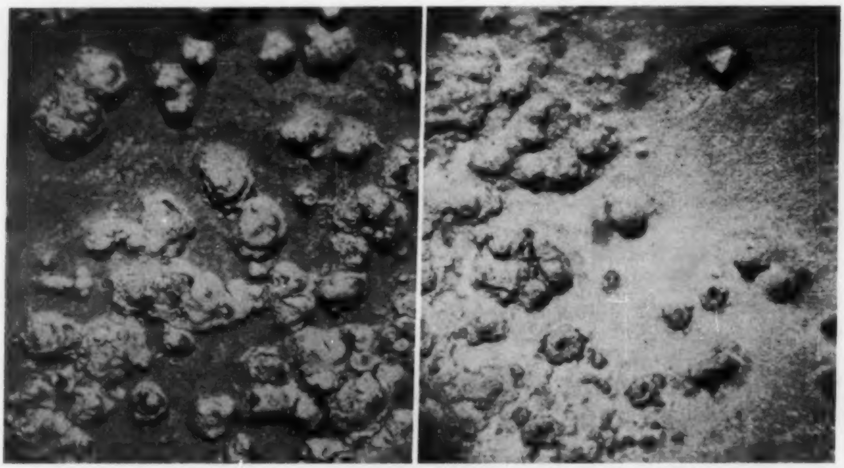

**Fig. 5. Impingement Attack on Copper Tube From Air Cooler Before and After Pickling**

*The photograph at the left shows impingement in an air cooler before pickling. The tubercle-like protrusions have an outer coating of iron oxide and an underlying layer of malachite. The appearance of the tube after pickling is shown at the right.*

normally form very light films on copper (unless it is the cathode of a galvanic cell) and are not particularly effective copper inhibitors. Consequently, it appears that the mechanical shielding of the copper surface by the light deposit was responsible for the inactivation of the impingement attack.

The deposits are rather loosely adherent and consist primarily of calcium phosphate and small amounts of zinc. The latter appears to be concentrated at the metal surface. The physical characteristics of these deposits are certainly not such that they would be expected to provide much resistance to mechanical removal.

The action of the loosely adherent deposit is difficult to explain if the impingement proceeds through mechanical disruption of the cuprous oxide as soon as it forms. One might expect the deposit to be more readily subject to mechanical removal than is the oxide film. Perhaps the action could be more readily explained if the higher velocities were found to remove the copper ions before oxide film formation could occur. Then the loose deposit would tend to retard removal of copper ions from the metal surface and thereby allow time for the oxide film to form. (Added effective life of the rather unstable cuprous ion would be afforded by reduction of cupric ions by the copper surface.)

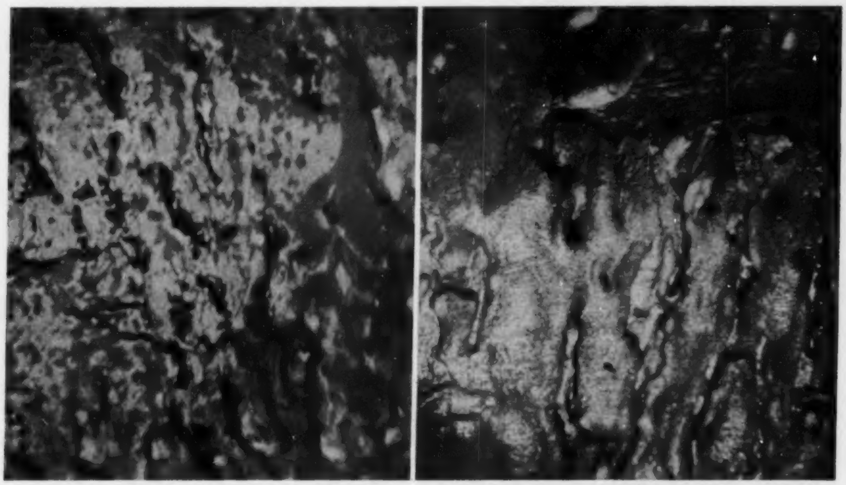

**Fig. 6. Impingement Attack of Copper in a Recirculating Hot-Water System Before and After Pickling**

*The photograph at the left shows impingement of copper tubing arrested by deposits; the same tubing after pickling is shown at the right.*

## Pitting Attack

Pitting of copper tubing is quite rare in potable waters and very unpredictable. A history of excellent service for a given supply is not absolute insurance that the next installation will not fail in a short time as a

result of perforation. Probably, the rarity with which copper pitting is encountered is chiefly responsible for the scarcity of information regarding the causes of the pitting. Laboratory study of the problem is markedly impeded by the difficulty of initiating pitting attack by any treatment that conceivably might be encountered in service. When pitting of copper in an actual system is investigated, pertinent detailed information about the system is generally scarce, primarily because the pitting is so unexpected.

### *Cold-Water Line*

Serious pitting of copper tubing was experienced in portions of cold-water (45–70°F) lines of an industrial system within 2 years of service. The well water supply employed was rather hard, but otherwise of good quality: total hardness (as $CaCO_3$), 240 ppm; total alkalinity (as $CaCO_3$), 197 ppm; chloride concentration, 6 ppm; sulfate concentration, 3 ppm; and pH, 7.8.

Portions of the lines showed light malachite (basic cupric carbonate) deposits and small amounts of silica, a very light general attack. Adjacent sections showed similar light deposits, but severe pitting. There was a marked concentration of pits on half the tube circumference but no specific orientation of the pitted half with respect to the position of the tube in service. The pits were on the top in some sections and on the bottom in others.

An explanation of such results seems impossible with reference to water characteristics alone. Further, no structural or compositional differences between the pitted and unpitted tubes could be detected. Differences in surface conditions were suspected to be the cause of the pitting more or less by a process of elimination. It was hypothesized that surface conditions on portions of some tubes rendered them particularly susceptible to localized attack. No peculiar surface conditions could be detected adjacent to the pits at the time the tubes were examined. Although this does not preclude the possibility that these conditions disappeared or became obscured during service, it provides no support to the hypothesis.

### *Sprinkler System*

A rather peculiar case where the pitting localized in one size of copper tubing was experienced in a sprinkler system served by a well water of apparently good quality: total hardness (as $CaCO_3$), 112 ppm; total alkalinity (as $CaCO_3$), 184 ppm; sulfate concentration, 9 ppm; chloride concentration, 35 ppm; and pH, 7.3.

The larger lines (1.25 in.) in this system pitted; the smaller lines (1 in.) did not. The pits in the larger copper tubing were much deeper on the bottom of the tubes than elsewhere; those in other portions of the tubes appeared to be just starting to develop.

The major portion of the tube surface was covered with a light-green deposit, which consisted of malachite (basic cupric carbonate) with a light covering of calcite and siliceous material. The thin deposit on the larger-size tube was occasionally broken on the bottom half by green malachite tubercules. The malachite was of a nodular (botryoidal) form, which is rather common for this material. Removal of the tubercules revealed pits partially filled with relatively coarse, well formed crystals of cuprous oxide.

The relatively thin malachite deposit on the unpitted areas of the larger tubing was rather loosely adherent and

could readily be flaked off. Scattered small bright areas were present in the underlying fine-grained cuprous oxide film. These bright spots are indicative of localized breakdown of the oxide film with active local attack of the metal surface. They are suggestive of an incipient stage of pit development.

The difference in the behavior of the two sizes of copper tubing appeared to reflect differences in surface conditions. The surface condition of the larger tubing seemed to be particularly susceptible to pitting attack. Here again there was no evidence of the specific surface condition involved. The advanced pit growth on the bottom of the tubes suggested that seepage and sediment collected in these buried lines during installation. But if this were true, no appreciable concentration of any sediment remained in the tube at the time of examination.

The relatively large crystals of cuprous oxide found within the pits are perhaps one of the more significant features revealed by laboratory examination of the tubes. The protective value of rather loosely bound crystals of this type might be expected to be almost negligible. They certainly would not form an effective barrier to isolate the underlying bare metal from the action of the water. Such relatively large crystals are indicative of slow growth. (Entirely apart from crystal size, slow growth is not conducive to protective film formation.) Apparently, the cuprous oxide formation was retarded, with the result that the bulk of the cuprous ions diffused away from the surface and oxidized. Slow crystal growth could result in a number of different ways—for example, increased solubility of cuprous oxide, complex formation with a resultant decreased cuprous ion concentration, and adsorption of foreign material on the crystals. Unfortunately, the reason for the slow oxide growth in this particular case remains obscure.

*Domestic Service Line*

Numerous failures of domestic copper service lines from pitting were encountered in a Canadian municipal system. One of the more peculiar features of this attack was its apparent initiation after the formation of a fine-grained oxide film had occurred, a film that normally might have been expected to be quite protective.

The well supply of the town, a hard bicarbonate water with a rather high sulfate concentration, had these characteristics: total hardness (as $CaCO_3$), 306 ppm; total alkalinity (as $CaCO_3$), 168 ppm; sulfate concentration, 160 ppm; chloride concentration, 1 ppm; and pH, 7.0.

Examination of the tubing showed pits in all stages of development, from mere bright spots to perforation of the tube wall. The major portion of the tube surface was covered with a thin, rather loosely adherent nodular green deposit of basic cupric carbonate. Beneath this was a smooth dark film. *In situ* x-ray examination of this dark film revealed only cuprous oxide. There were numerous small breaks in the dark film where a pitting attack appeared to be active. Relatively large, well formed crystals of cuprous oxide were present in and adjacent to the pits. The dark film also was disrupted in a band roughly $\frac{3}{8}$ in. wide extending lengthwise along the tube. This band showed numerous clumps of rather coarse cuprous oxide crystals, together with areas of apparently bare metal. The smooth, dark, oxide film was rather loosely adherent to the metal surface in the areas adjacent to the pits

and could be chipped off quite readily. The underside of the film consisted of relatively large cuprous oxide crystals.

The general appearance of the pits is shown in Fig. 7. The white spots within the pit at the left are a result of light reflections from properly orientated faces of the relatively large cuprous oxide crystals on the pit surface. The dark area immediately above and to the left of this pit also consists of coarse cuprous oxide crystals. The area around the pits and extending to the lower right corner of the photograph is bare copper; the light spots in this area result from reflections from the roughened metal surface. The light spot in the lower portion of the pit at the right also results from bare copper. The upper and lower left portions of the photograph show the relatively smooth oxide film. At the left and extreme right of the pits are portions of the overlying malachite layer.

**Fig. 7. Pits in Domestic Copper Water Line**

*The white spots in the two pits are caused by light being reflected from crystals or from bare copper.*

Normally, growth of the oxide film would be expected to proceed from the outer surface—that is, by outward diffusion of cuprous ions through the oxide film and subsequent additional oxide formation. The appearance of these tubes, however, suggests that the coarse oxide crystals slowly formed under the initial fine-grained oxide film. It is possible that the film was excessively porous. Apparently, the large crystals disrupted the fine-grained oxide film in numerous areas and exposed the underlying bare metal to attack. Where the fine-grained oxide film was disrupted over a rather wide area—such as the band extending along the tube—attack of the metal was of an essentially uniform nature. Pitting resulted where the film was disrupted in more localized areas. This suggests that the film-covered surfaces were markedly cathodic to these bare areas.

### *Hot-Water Line*

A recent pitting failure of a copper line in a Pittsburgh district is perhaps of interest, particularly in view of the good service generally obtained with copper in this locality. The line in question carried very hot water (180–200°F) and failed after 3–4 years of service. The very high temperature undoubtedly contributed to the attack. The water was a lime-soda–softened surface supply of the following average composition: total hardness (as $CaCO_3$), 100 ppm; total alkalinity (as $CaCO_3$), 30 ppm; sulfate concentration, 150 ppm; chloride concentration, 18 ppm; and pH, 8.5.

The high temperature combined with a relatively high pH resulted in the formation of a hard, dense scale roughly $\frac{1}{16}$ in. in thickness. The scale consisted of a white deposit sandwiched between two dark-brown layers. Spec-

trographic analysis showed the following metals to be present: major—aluminum; low major—calcium, silica, magnesium, and copper; minor—iron and manganese; and low minor—nickel. Calcium carbonate, cuprous oxide, a hydrated aluminum silicate, a basic magnesium compound with a serpentine structure, and hydrated manganese oxide were among the constituents present. The low minor of nickel is somewhat unusual and apparently represents pickup from equipment ahead of the copper line. The dense, adherent character of the deposit might lead one to expect that it was protective, but such was not the case. Numerous, very small pits extended completely through the metal. The pits were filled with relatively coarse cuprous oxide crystals.

In many places on the line, the cuprous oxide was too coarse to provide a good protective film. As a result, attack on the underlying metal continued, and the coarse oxide layer on the affected areas thickened. Eventually, penetration of the metal resulted from a pit filled with rather coarse oxide. In this instance, the scale apparently retarded the escape of water sufficiently to allow it to just seep out through the porous oxide plugs. As in the domestic service line mentioned before, the cuprous oxide probably formed too slowly to provide a fine-grained protective film.

Manganese deposits were reported by Campbell[3] to cause pitting of copper in soft waters. He also found certain waters to contain a natural inhibitor, the exact nature of which is unknown, that prevents such pitting. The inhibitor, however, is removed by an alum floc, and would probably be absent in this case. It seems difficult to attribute the pitting to manganese deposits, in view of the excellent service provided by copper tubing in other installations served by the same water supply. Moreover, numerous systems in the Pittsburgh district use Allegheny, Monongahela, or Ohio River supplies that cause problems due to manganese deposits, yet seem to cause little trouble from copper pitting.

*Other Causes of Pitting*

Campbell[4] also found that carbonized residues formed during tube manufacture by thermal decomposition of the drawing lubricants cause pitting of copper in hard waters (waters with $CaCO_3$ concentrations greater than 100 ppm). Residues of this type are reputed to be quite rare with tubes drawn in the United States. In no case encountered by the author were definite residues of this type found when the pitted tube was examined, although in at least one instance the initial presence of the residues was suspected. In all the cases discussed here, metal surfaces and deposits were checked for the presence of carbonized material and manganese.

The initial condition of a metal surface is often suspected of being favorable to pitting attack. Generally this idea is difficult to prove; in none of the cases discussed has such proof been demonstrated.

On several occasions, definite damage to the metal surface during storage or fabrication of equipment has been observed, but these appear to have been rather special cases. In one instance, pits were found in the copper tubes of a condenser that had never been in service. The tubes had been soldered into the tube sheet, and the flux—apparently a very corrosive one—had run down the interior of the tube and pitted the surface. In another instance, greenish spots were observed on the

interior of soft copper tubing stored as an unwrapped coil. The spots consisted of crystals of cupric chloride; under each crystal the metal was pitted.

The coarse crystals of cuprous oxide found in several of the examples discussed before were present in most cases of copper pitting observed by the author. Similar crystals also were noted by Campbell[3,4] in conjunction with pitting of copper. From the physical nature of these crystals, they would not be expected to provide a particularly protective barrier; the condition of the underlying metal proves that they did not. The large crystals are indicative of rather slow growth.

The factors responsible for the slow formation of the relatively large cuprous oxide crystals apparently involve the condition of the metal surface. If the factors were solely dependent on the water composition, pitting attack, if encountered, would be expected throughout the system; this is rarely true. The manner in which the metal surface influences the rate of oxide crystallization seems rather puzzling. There are several conceivable mechanisms whereby this might occur, but no evidence points to a mechanism that is actually operative.

The cases of copper pitting discussed do not permit conclusions to be drawn with regard to the influence of water composition on pitting attack. But it may be of interest to note that the pH range was 7–8.5 in these cases, a range in which few difficulties from general attack would be expected.

At least in the cases investigated, the chief protective film appears to be cuprous oxide. Such basic cupric salts as the basic carbonates may reinforce this film, but they do not appear to suffice in the absence of an essentially continuous cuprous oxide film. The attack generally proceeds at a very slow rate as long as this oxide remains in good repair. Apparently, even under normal conditions, the cuprous ions must effectively remain adjacent to the metal surface for an appreciable time to permit formation of the oxide. When they are removed too fast—during impingement, for example—rapid attack ensues. Rapid attack also can occur—in the absence of excessive flow velocities—if formation of the cuprous oxide is abnormally slow. If this happens, relatively large cuprous oxide crystals that afford incomplete surface coverage will form. When large areas of the metal are thus affected, an essentially general attack occurs at an abnormal rate; when only small local areas are so affected, pitting results.

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# Use of Peak Demand Data in Design and Operation

**Holly A. Cornell**

*A paper presented on Jun. 8, 1961, at the Annual Conference, Detroit, Mich., by Holly A. Cornell, Partner, Cornell, Howland, Hayes & Merryfield, Cons. Engrs., Seattle, Wash.*

THE rapid increase of peak demands on distribution systems in recent years has intensified the need for methods of predicting a system's peak demand capability. With the increased use of ground storage and pumps to supply the peak requirements, and with the development of multilevel systems interconnected by pumps and regulating valves, distribution system operation has become quite complex. The planning for additions to distribution systems has likewise become complex.

Long before methods for the analysis of flow in pipe networks were available, distribution systems were planned and operated by trial and error with quite satisfactory results. With the development of centralized telemetering and supervisory control, this procedure, used with judgment and experience, is often quite successful in correcting operational difficulties and planning additions to existing systems. This trial and error procedure is suitable for a gradual improvement of a network in which changes are made a step at a time, between periods of observation when the effect of the changes can be evaluated. But because of the accelerated development since World War II, time is not always available to apply this procedure properly. Thus engineers have been led to seek better methods of predicting the flow and pressure in a network in order to anticipate and correct operating difficulties and inadequate distribution facilities before frantic calls to the water office point them out.

The determination of flow and pressure in a distribution system through the use of analytic procedures has been possible for many years. Three methods are commonly used. Briefly described, these are:

1. Computation by a trained engineer or technician applying the method of successive corrections developed by Hardy Cross [1] (hand method).

2. Computation by digital computer applying the method of successive corrections developed by Cross (computer method).

3. Measurement of the current and voltage in an analogous electrical network, using a network analyzer * (analog method).

This article will consider the utilization of known or predicted peak-demand data in the development of operating procedures, and in the planning of new facilities by the analytic methods described above.

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* McIlroy Pipeline-Network Analyzer, Standard Electric Time Co., Springfield, Mass.

**Characteristics of Peak Demand**

Dependable data on the peak demands that must be met by a water distribution system are not plentiful. Until recently, systematic collection and study of such data had never been undertaken. Committee 4440 M—Water Use began a study in 1957. This committee collected considerable information from various parts of the country and evaluated this data in terms of the ratio between the average demand for the year and the demand during the peak day and the peak hour.[2] In this study it was found that the peak-day demand correlated with climate, but that the demand for the peak hour was more closely related to the nature of the community than to climate. The mean ratio between the peak day demand and the average yearly demand in the humid areas of the United States appeared from these studies to be approximately 1.60:1. By statistical methods, it was found that this ratio could reach a value as high as 1.88:1 once in 20 years and 2.0:1 once in 100 years.

These data were based on systems serving more than 10,000 people. In the smaller systems, it is believed that the ratio would be larger. It appeared that in arid areas in the United States, the ratio between the peak day demand and the average yearly demand lies in the range of 2.0–2.6:1, with values as high as 2.36–3.03:1 occurring once in 20 years and 2.51–3.2:1 once in 100 years.

Data from six utilities across the country indicated ratios of maximum-hour demand to maximum-day demand of 1.5–2.0:1, with extremes of 1.8–2.2:1 occurring once in 20 years and 1.9–2.3:1 occurring once in 100 years. Based on the 20-year frequency, the rate of demand during the maximum hour could be 3.4–6.6 times the average demand for the year. The peak hourly rate of demand is of primary interest in distribution network studies. Despite the extreme variations indicated, this statistical approach to peak demand determination, when applied to adequate experience data classified according to climate, offers the best possibility for prediction of future peak demand yet developed.

Accurate data on peak demand are essential when making an analysis of the flow in a distribution network. Adequate metering facilities and continuous and accurate records of demand are indispensable. Normally the peak hourly rate of demand is determined from a master recording meter or from a combination of readings from master meters, pumping equipment, and reservoir levels. These data do not necessarily provide information on the distribution of this demand throughout the system. Long-term (monthly or quarterly) average consumption records may be used to establish peak demand for subareas of a system by applying the ratio of average demand to peak demand and a proper diversity factor. Proportioning of peak demand to subareas can also be based on an estimate of the developed areas served and a previously determined peak demand rate per unit of area. In arid locations, where lawn sprinkling is the principal consumptive use during the peak period, the peak demand is probably more closely related to area served than to population.

Even though the peak demand can be determined for a given water system as it now exists, the planning of distribution networks requires the prediction of the peak demand in the fu-

ture, as underground pipes remain in service for 50 years or more. For short-term periods in the range of 1–10 years, it is possible to make reasonably dependable predictions. Estimates of peak demand for periods of 10–25 years in the future are less certain, but where the area to be served can be established and a zoning plan for the area has been adopted, predictions suitable for reasonably accurate sizing of distribution piping are possible. Long-term predictions, covering periods of 25–50 years ahead, are questionable because peak demand is so greatly influenced by economic conditions and mode of life. In 1930, it would have been difficult to predict the present tremendous suburban development with its extensive home areas and facilities for outdoor living.

## Methods of Analysis

The original analytic procedure for the determination of flows in pipe networks was developed by Cross.[1] The procedure was a by-product of the development of the moment distribution method for the analysis of continuous frames.

The synopsis of the original paper by Cross includes this statement: "Perhaps the greatest value of the method is in training and assisting judgment, but this, of course, is the principal object of all analytic procedures." Neither the analytic procedure as developed by Cross nor the electronic computer can be substituted for judgment and experience. Until much more elaborate computer programs than those currently available are developed, the hard work of reaching a decision on the basis of incomplete, questionable, and often conflicting information must still be performed by a human being. There is a tendency, as is often the case with elaborate systems of analysis, to place great faith in the results of a network analysis simply because they are obtained by an erudite method or a complicated machine. Such an attitude is dangerous. No analysis is more dependable than the assumptions and data on which it is based. The computer, regardless of type, is not yet capable of examining the pipe and deducing a proper coefficient of friction, or of guessing what the future demand may be. Thus all analyses must be viewed only as tools that the operator or designer uses to assist his judgment on the needs of a system.

The Cross method for the analysis of flow in networks is, typically, relatively simple in principle. It involves an initial assumption or guess of the flow distribution that follows the rule of continuity of flow. This initial guess is then successively corrected by an arithmetical application of the fundamental principle of the differential calculus until the change in head or potential along any closed path is zero. The principle of continuity of flow and continuity of potential are essentially a statement of Kirchoff's law. The method of determining the correction to be applied is not precise in all cases, but the rate of convergence of the procedure, despite this inaccuracy, is sufficiently rapid to develop satisfactory answers in most cases. The procedure may be carried to any degree of accuracy depending entirely on the need and the time available. This rate of convergence is greatly influenced by the initial flow distribution guess and by the experience of the person making the analysis. To illustrate, the network used later to compare methods of analysis was analyzed in 7 hr by an engineer experienced in the analysis;

12 hr was required for the same analysis by an engineer who had applied the method only once or twice before, but had wide experience in the water distribution field. Application of the method by hand is economical for a small system. By skeletonizing the system—that is, by combining several pipes into one equivalent pipe—it can be used to analyze any system. It is particularly adapted to preliminary sizing and to overall master plan development where exact analytic results are an unnecessary refinement. Many variations on the basic procedure have been devised, such as the method of balancing equivalent pipe lengths developed by Long and colleagues.[8] Nomographs for rapid determination of head loss and many other shortcuts are useful to the analyst who is engaged in this type of work regularly.

The Cross method of analysis can be programed for an electronic digital computer. The computer is first supplied data on the characteristics of each pipe in the system, on the conformation of each loop or connection within the system, and on the supply and demand points and quantities. The computer is also supplied an initial flow estimate which meets the requirements of continuity of flow. The time required by the computer to obtain a result is again dependent on the initial estimate of flow, and can be greatly reduced if the initial estimate is prepared by an experienced analyzer of distribution systems. The programs for this type of computer solution are available for the several types of computers now in use, although not all have been published. In some of these programs certain adjustments of the basic Cross procedure have been made in order to accelerate the convergence. The results of an analysis are read out directly in terms of pressure loss and flow in each element of the network. These data, though convenient, generally must be transferred to a diagram of the system in order to insure that the results are reasonable and can be readily understood.

The third method of analyzing flow in a network is by using the network analyzer. This analyzer is essentially an analogous electrical circuit that produces the same relationship between current and voltage drop as exists between flow and head loss in the prototype distribution system. The key to the analyzer is the fluistor, a vacuum tube having the characteristic that the voltage drop is proportional to the 1.85 power of the current flowing. Thus its characteristics are similar to those of a pipeline following the well known Hazen-Williams formula for head loss. The supply in the prototype system is simulated on an analyzer by an electric current source. Once the system has been simulated on this analyzer by the installation of the required model electrical circuits, any number of flow conditions can be rapidly checked and the head losses determined. The results are read directly by use of a properly calibrated galvanometer.

## Sources of Error

In any of these systems of analysis, the difficulties are not basically related to involved theoretical considerations, but to the mass of separate computations or current and voltage readings that must be made, indicating a real need for logical and accurate systems of bookkeeping. Whether by hand, by computer, or by analog, careful checking of input and output and systematic recording of the results is essential. Incorrect results are caused by human

error. The writer has found that, in the use of any of these methods, a complete tabulation of flows on a diagram of the system is essential for each condition that is being analyzed. Only by such a tabulation can errors be discovered. This is necessary for the same reason that Cross always insisted that the structural analyst must sketch the "deflected structure." Unfortunately, even the computers cannot read the operator's mind; they do not know when he has listed an incorrect flow or friction coefficient, has inserted the wrong fluistor for a given element of the system. Only by examining a tabulated flow sheet, using the logic and understanding of experience, is it possible to see what errors have crept in.

The previously mentioned uncertainty regarding the peak demand used in applying the analysis is only one of the variables that can cause even the most elaborate computer analysis to be unreliable. Another important but uncertain factor that must be established before analysis is the friction loss characteristic of the pipes in the system. The actual friction coefficient will be found to vary widely, depending on the age of the pipeline, the chemical characteristics of the water, the material of which the pipe is constructed, and whether the flow is laminar or turbulent.

It is not the purpose of this article to discuss the merits of the Hazen-Williams basis for determining head loss relative to the Darcy relation, applied with due regard to Reynolds number and the roughness coefficient that results in a varying resistance to flow. The matter is thoroughly covered in existing literature. It is sufficient to state that the many other uncertainties involved in a practical application of network analysis seldom justify the use of elaborate or complicated methods for determining head loss. There is something to be said for adherence to the long and widely used Hazen-Williams formula, not because it is necessarily correct, but because almost all experience is expressed in its terms. The most dependable method of establishing friction characteristics is to analyze a system for a known condition of flow for which complete data on the actual losses in the system are available. Even this procedure may be misleading if the flow is so low as to result in a laminar flow condition in some portions of the system. But the uncertainty inherent in the prediction of future friction loss characteristics is not decreased by an exact knowledge of existing conditions unless supplemented by long experience in the operation of a given system and the corrosive characteristics of the water carried.

**Relative Advantages of Methods**

To those who are contemplating the use of analysis in developing or operating a water distribution system, a comparison of the three methods may be of interest. The basic hand method of analysis requires only the time of a single individual to proceed through the laborious but simple method developed by Cross.

The use of the electronic digital computer requires a program, and a sufficient understanding of this program, to set forth the data in a form that can be fed into the machine. Computer centers now have programs that make it unnecessary for the water system operator or designer to have detailed knowledge of computer programing. Forms are provided on

which each pipeline in the system is given a number. The friction characteristics (loss of head for unit quantity of flow) and initial flow assumption for each pipeline are tabulated. These data are then punched on cards or fed into the machine on tape, as the case may be, and the machine proceeds through the analysis to the accuracy specified. The results are read out on the usual form for the computer being used, listing for each pipe or element the computed flow and the loss in head. This entire procedure can now be completed by mail; the water system personnel need not even know what an electronic digital computer looks like.

The electric analog computer requires an initial setup by a technician sufficiently familiar with the theory of the analogy to simulate the prototype system from a diagram of the actual system to be analyzed. Once this has been done, the supply and consumption points are connected and a current applied to the computer. The flow and head losses are then read and recorded. The analog method is not well adapted to remote solution by transmitting problems by mail, but this is only because once the analyzer is set up for a specific system, it cannot be used for any other system.

TABLE 1

*Comparative Cost of Methods of Analysis*

| Method and Item | First Analysis | | | Added Analyses | | |
|---|---|---|---|---|---|---|
| | Hours | Cost per Hour $ | Total Cost $ | Number of Analyses | Cost $ | Cost per Analysis $ |
| Hand | | | | | | |
| Solution by engineer | 7.0 | 8.50 | 59.50 | 1 | 42.50* | 42.50 |
| Computer | | | | | | |
| Key punching & verifying | 2.0 | 4.75 | 9.50 | | | |
| Listing | 0.1 | 20.00 | 2.00 | | | |
| Computer time | 0.7 | 80.00 | 56.00 | | | |
| Punch cards & paper | | | 2.87 | | | |
| Transfer listed results to system diagram by draftsman | 1.0 | 5.25 | 5.25 | | | |
| *Total* | | | 75.62 | 3 | 147.51 | 49.17 |
| Analog | | | | | | |
| Set up system on analyzer by technician | 9.0 | 8.00 | 72.00 | | | |
| Analyzer operating time | 4.0 | 12.00 | 48.00 | | | |
| Engineer | 4.0 | 8.50 | 34.00 | | | |
| *Total* | | | 154.00 | 8 | 357.87 | 44.73 |

* Estimated time. Not actually performed.

For large systems, analysis by hand requires skeletonization, or too much labor is involved. Analysis by digital computer is rapid once the problem has been programed and the basic data supplied. Repeated analysis of the same system under many flow conditions, or with only a few elements of

the system altered, is even more rapid with the computer. By the analog method, once the system has been simulated, analysis for revised flow conditions can also be made rapidly. Any of the methods can be adapted for special conditions, such as incorporation of pump rating curves or varying storage levels. Such special conditions are much more difficult to include in a hand analysis simply because of the labor involved.

The author recently made a comparison of the three methods of analysis on the same system, and the results illustrate the above discussion. The comparative analyses were made for an intermediate step in the development of plans for expansion of the system. Previous analyses for an actual flow condition had been used to establish the head loss characteristics. The somewhat skeletonized system consisted of 30 loops and 75 lines or elements. A diagram of this system, with pipe sizes, assumed friction characteristics (*K* or *R* factors), loads and sources of supply, and initial estimates of flow distribution is shown in Fig. 1. The skeletonized system and the initial estimate of flow were developed by an engineer experienced in this type of work. From this point the analysis was performed by the three methods independently, each being carried to an accuracy specified as an error not to exceed 5 ft head loss around any loop. This requirement, of course, has no bearing on the analysis when made by the analog method, as the accuracy in that case is entirely dependent on the accuracy of the instrument used to read the voltage drop and current flow.

The time and the cost involved, using published rates of charges for computers and normal hourly costs for personnel including overhead costs, are shown in Table 1. The hand analysis was performed by an experienced engineer who had been working in water distribution network analysis, from time to time, for 10 years. The analysis by digital computer was performed by a machine * operated by a Portland, Ore., company. The analysis by the analog method was performed on the analyzer at Washington State University. Three additional analyses were made by computer with five pipe elements changed in one case and a revised flow condition together with minor pipe element changes in the two other analyses. Table 1 indicates the average cost of these three additional analyses. Eight additional analyses after the first were made on the analog analyzer, some involving considerable change in pipe size and flow conditions. The average costs of these analyses are also shown in Table 1.

Table 1 indicates that the cost of the first analysis was far greater for the analog method than for the other two methods. This, of course, reflects the time for setting up, for checking the circuits and resistors, and for eliminating errors; with the computer, the major cost involved was in actual computing.

It is the author's opinion that the system operator or designer who is to use the results must be present during the actual tabulation of results when the analog method is used. Only in this way is it certain that the correct system is analyzed. The person who is to use the results must also be present to study the results of the analysis and determine the next step, because under normal conditions, the analyzer cannot stand idle while its operator

* IBM 650, International Business Machines Corp., New York.

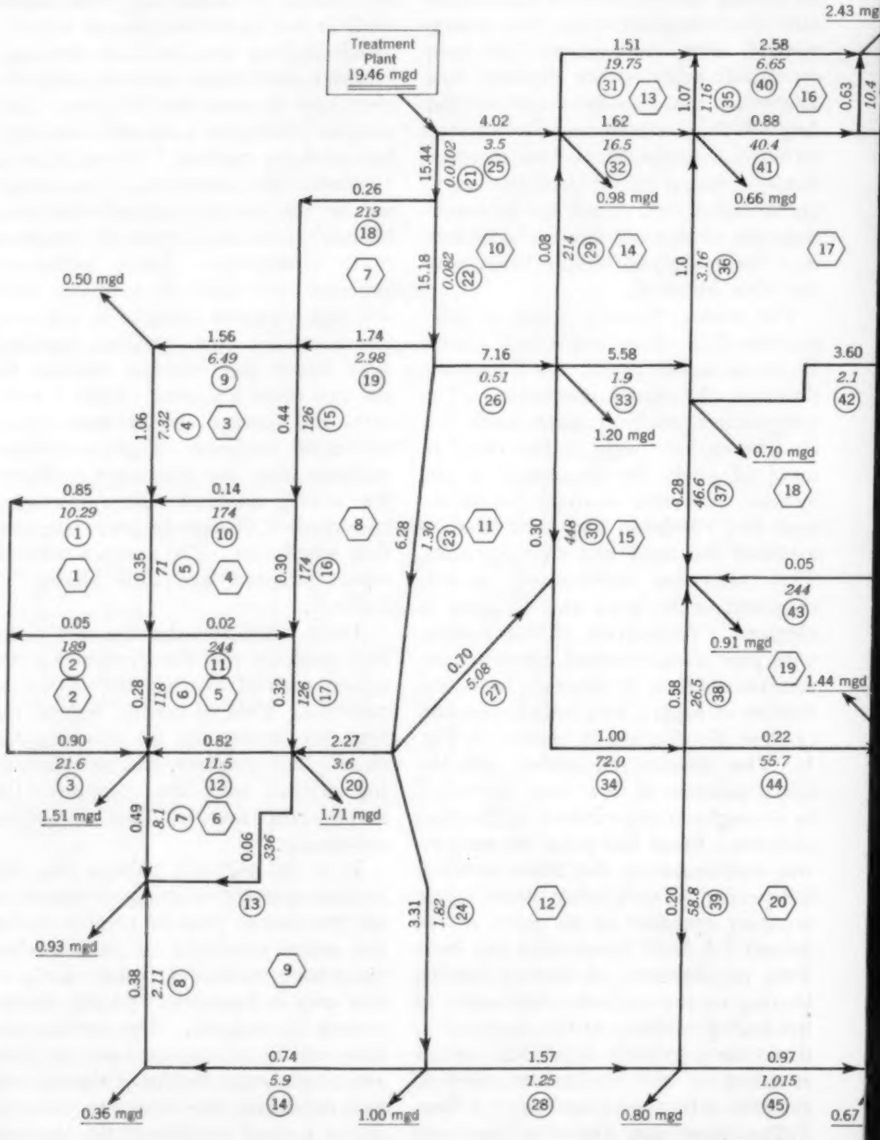
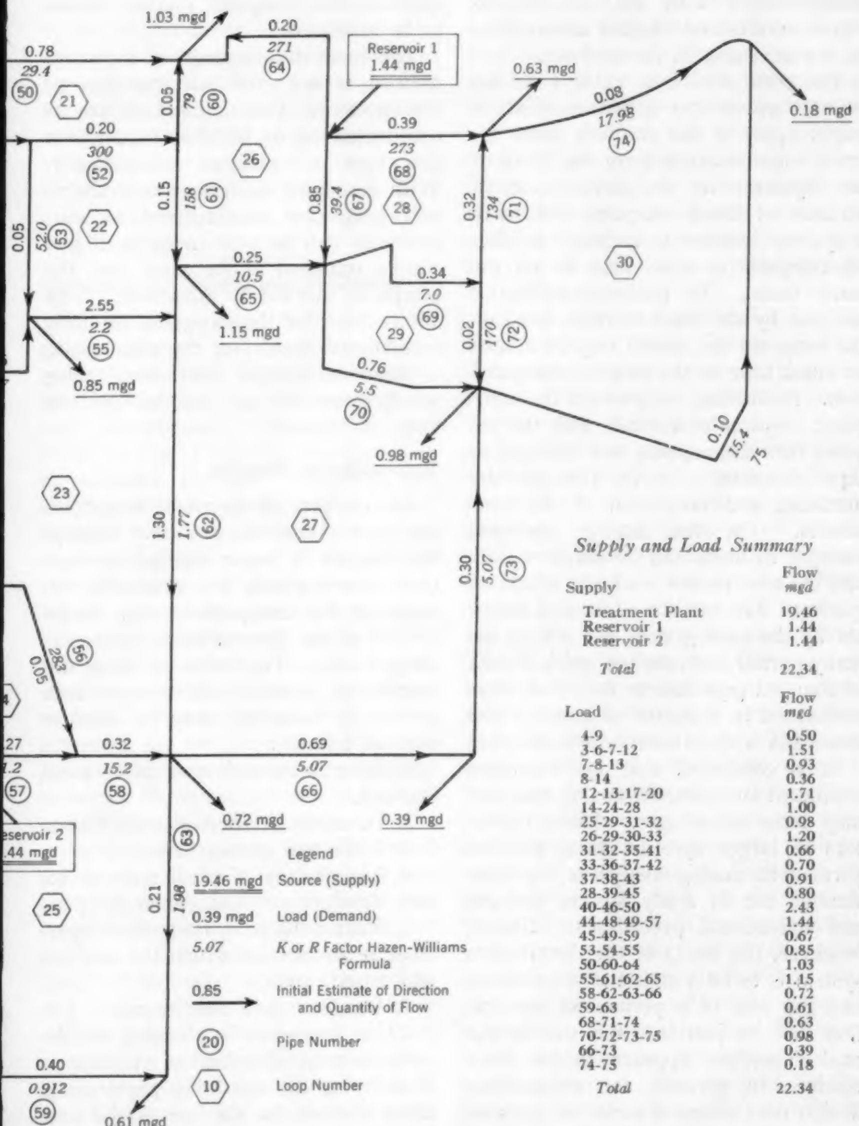



Fig. 1. Distribution Sys




*Supply and Load Summary*

| Supply | Flow *mgd* |
|---|---|
| Treatment Plant | 19.46 |
| Reservoir 1 | 1.44 |
| Reservoir 2 | 1.44 |
| *Total* | 22.34 |

| Load | Flow *mgd* |
|---|---|
| 4-9 | 0.50 |
| 3-6-7-12 | 1.51 |
| 7-8-13 | 0.93 |
| 8-14 | 0.36 |
| 12-13-17-20 | 1.71 |
| 14-24-28 | 1.00 |
| 25-29-31-32 | 0.98 |
| 26-29-30-33 | 1.20 |
| 31-32-35-41 | 0.66 |
| 33-36-37-42 | 0.70 |
| 37-38-43 | 0.91 |
| 28-39-45 | 0.80 |
| 40-46-50 | 2.43 |
| 44-48-49-57 | 1.44 |
| 45-49-59 | 0.67 |
| 53-54-55 | 0.85 |
| 50-60-64 | 1.03 |
| 55-61-62-65 | 1.15 |
| 58-62-63-66 | 0.72 |
| 59-63 | 0.61 |
| 68-71-74 | 0.63 |
| 70-72-73-75 | 0.98 |
| 66-73 | 0.39 |
| 74-75 | 0.18 |
| *Total* | 22.34 |

**n No Elevated Storage**

communicates with the designer to report results and receive instructions on the next step in the analysis.

The costs shown in Table 1 do not include travel and subsistence which might apply if the analyzer were located some distance from the office of the operator or designer. Cost of transfer of listed computer results to a system diagram is included so that all comparative costs may be on the same basis. To perform additional analysis by the hand method, even on the same system, would require almost as much time as the original computation. Additional analyses on the computer requires new cards with the revised flow assumption and changes in pipe elements, a rerun through the machine, and tabulation of the new results. On the analog analyzer, changes in loads can be made rapidly and the new results read and tabulated quickly. The cost for additional analyses by the analog does not reflect the many partial analyses and quick checks of changed pipe size or flow that were performed in a matter of minutes and discarded without complete tabulation.

It is concluded that for extensive continued analyses, the analog analyzer may have advantages. Many operators of larger systems have installed permanent analog analyzers for continuous use in study system changes and operational procedures. Unless, however, the study of the distribution system is to be a continuous operation and the cost of a permanent installation can be justified, the use of the analog method appears to be more costly. In general, for engineering design uses where a series of analyses of a system are to be made once and incorporated in a development program that will not be reconsidered for a matter of years, the use of either the hand or the computer method seems to be indicated.

The basic disadvantage of the hand method is not cost but boredom of the operator. Few individuals are so constituted as to be able to perform this type of analysis continuously. With computer centers now available and programs standardized so that problems can be sent in by mail and results returned in the same day, the computer method is attractive. This allows time for the designers to study results and decide on the next move, a basic advantage over the analog which, once set up, can be used on only one system.

## Approximate Results

All analyses of distribution systems are approximations, not only because the analysis is never carried to complete convergence, but primarily because of the inaccuracies and uncertainties of the data on which the analysis is based. The cause of these uncertainties, some of which have been previously discussed, may be listed in part as follows:

1. Inaccurate estimates of present demand,
2. Incorrect friction characteristics,
3. Unknown system losses,
4. Uncertainty of predictions of future development and demand,
5. Variations from the system operating procedure on which the analysis was based, and
6. Laminar flow conditions.

Those interested in planning the development of distribution systems or in studying the operating problems of those systems by the use of the analytic methods must constantly bear in mind that the reliability of the results obtained is dependent on the above factors and not on the method of

analysis used. By careful evaluation of the uncertainties of the basic data, and by adjustments of the results to account for these factors, it is possible to utilize the results of theoretical analysis to establish programs for development and operation. The possibilities for erroneous conclusions if these factors are not properly evaluated is serious.

### Solutions to Operating Problems

With the increased development of ground storage and pumping as opposed to elevated storage, the operation of distribution systems becomes more complicated. The system illustrated in Fig. 1 actually operates with no elevated storage. Pressures are maintained at a satisfactory level entirely by the manipulation of the pumps at the supply point and at the ground storage reservoirs within the system. As the system is operated in connection with a continuously manned electric power-generating station, supervisory control is available. With continuous telemetering of the system pressures to the supervisory control point, pumps can be started or stopped as needed to maintain satisfactory pressures throughout the system.

As systems such as that illustrated are developed, the ground storage and pumping facilities become more numerous, the piping network more extensive, and operation more complicated. Eventually, simple observation of a series of pressure readings from various points in the system will not be sufficient to insure that ground storage is replenished during the off-peak period and available again during the peak demand hours. Careful programing of the system operation must be undertaken, and the rate of bleedoff into ground storage during off-peak periods must be sufficient to insure refill by the time the peak demand period again begins. The pressure in a system with no elevated storage is a function of the pumping capacity in operation and of the setting of the bleed-off or pressure-reducing valves. Thus a condition is quite possible in which the pressure in the system is maintained at an adequate level, but the rate of refill of the ground storage is inadequate.

The analyst and statistician for the Department of Water Works, Dallas, Tex., reports, for example, that the Dallas low-pressure system includes five ground storage reservoirs with supply by two pump stations. The problem is to fill all reservoirs by 8 AM without spilling, and at the same time not valving down to an extent that will back up the head against the input stations and cut back their output. Such a problem can be studied by the use of analytic procedures. The Dallas analyst has developed a method of incorporating pump characteristics into the Cross analysis and applying this through a digital computer. Thus, if dependable demand data can be developed, a distribution system analysis can be used for programing operating procedures. Where the input supply, as at Dallas, is in the order of 100 mgd, the increase in pressure under which the system operates can seriously affect the total production of the supply facilities, and can also seriously affect the cost of operation. Analytic studies that may seem expensive to the operator of a small system are often justified for the larger systems where high expenses are involved in pumping.

Another operating problem that is often particularly troublesome is the case in which systems of two, three,

or more levels are interconnected by pumps and regulating valves and are all supplied through the main (usually the lowest-level) system. In such cases the proper selection of pumps and the optimum use of storage are not always readily apparent to the operator.

thereby eliminate the need for two of the four booster pumps (Booster A and B), which were currently used to deliver water from the low-level system to the high-level system. A preliminary examination indicated that this procedure might give trouble, and a flow analysis was undertaken to in-

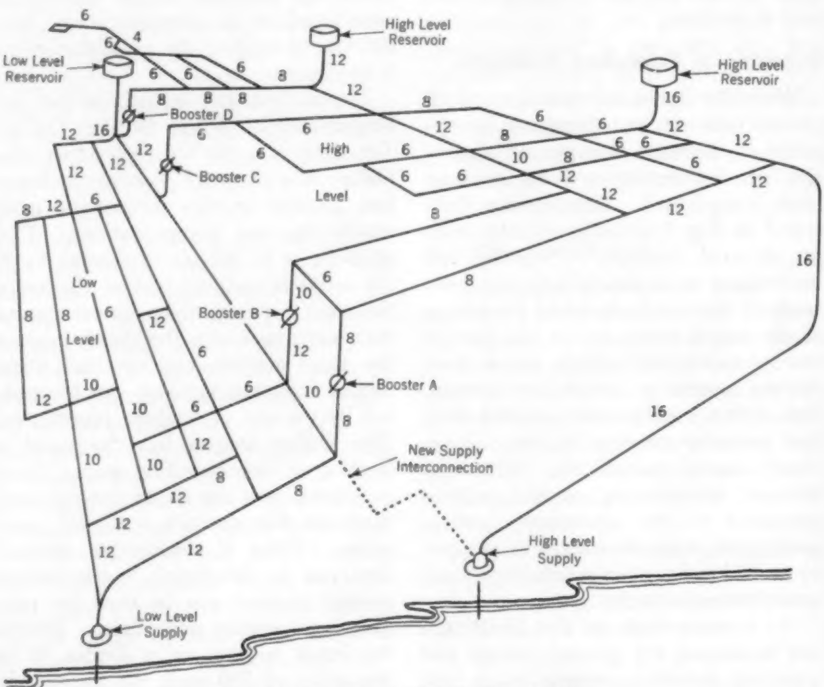



**Fig. 2. Two-Level Distribution System**

*Numbers by pipelines indicate diameter in inches.*

An example of this situation recently came to the author's attention. A general outline of the system concerned is shown in Fig. 2. In this case, additional supply was developed at a point where transmission facilities existed only to the upper-level system. The system operator planned to increase the supply pumps at this point and

sure that it would be safe to remove the two booster pumps. The analysis indicated that the piping network of the high-level system was inadequate for this method of operation. Thus, even though the added supply was sufficient to meet the demand of the high-level system with the two booster pumps eliminated, inadequate pressure

would result. On the basis of the results of this analysis, the two booster pumps were continued in service and a supply interconnection constructed from the new source to the low-level distribution system. The theoretical analysis in this case allowed the operator to predict an operating problem in advance of its occurrence and to take corrective measures in time.

Flow analysis can also be used to study the condition of the pipe in a system. The system shown in Fig. 1 was initially analyzed for a known condition of flow and pressure to establish the friction characteristics of the pipe in the system. A good agreement between measured and computed flow and pressure could be obtained, but only if a Hazen-Williams $C$ value of approximately 65 was applied. This led to a careful investigation of pipe condition, including the actual removal of several sections of pipe. The field examination confirmed the analytic results, as all pipe examined was found to be badly tuberculated, with encrustation of 1–2 in. in thickness found in almost all pipe examined that was over 10 years old. Some indication of this condition had been apparent to the maintenance crews for some time, but its importance had never been fully realized by management. The investigation resulted in giving more attention to corrosion control measures through treatment, and in using cement-lined pipe for all new installations.

The analytic procedure can be used for the development of forced circulation in distribution systems for quality control or to prevent freezing. An interesting use of the procedure was recently reported [5] by Larson, Guillou and Henley in the development of a circulation plan to prevent red water in end loops. These investigations utilized the Moody diagram of variable friction coefficient with the Darcy equation. The investigators were therefore able to include the effect of laminar flow where it occurred.

An analysis of flow in a distribution network, provided it can be based on adequate information on pipe characteristics and demand conditions, will provide a system operator with a picture of what may often be a very complex situation. This gives him confidence and understanding, allows him to become familiar with the operation more rapidly, enables him to evaluate the effect of changes in the operation quickly, and provides a basis for the development of judgment and experience much more readily, all by providing knowledge of the distribution of flow within the system.

Yet, analysis is still only a tool. The results are no better than the data on which the analysis is based. It can duplicate the results for an existing situation, but its ability to predict the future still depends on the basic ability of someone to supply the proper information.

### Planning Future Construction

The limitations of the use of distribution system analysis in planning future construction have already been discussed. Successful planning must be based on adequate predictions of the future rate of peak demand, of future pipe characteristics, and of the area to be served in the future. The methods of analysis available are much more accurate than the assumptions on which the analysis is based.

Nevertheless, the advantage of future planning in the development of a system is considerable. If a depend-

able master plan can be developed, the extension of the system can follow a pattern that will allow the proper pipe size to be installed initially and will insure that mains are properly located for the future. The development of such a master plan usually involves only the trunk and feeder mains. advance can be quite accurate, and the friction losses can be developed on the basis of actual experience at the time. Analysis can be used under these circumstances to locate trouble areas where low pressures or inadequate supplies may soon exist, or to determine the pump characteristics neces-

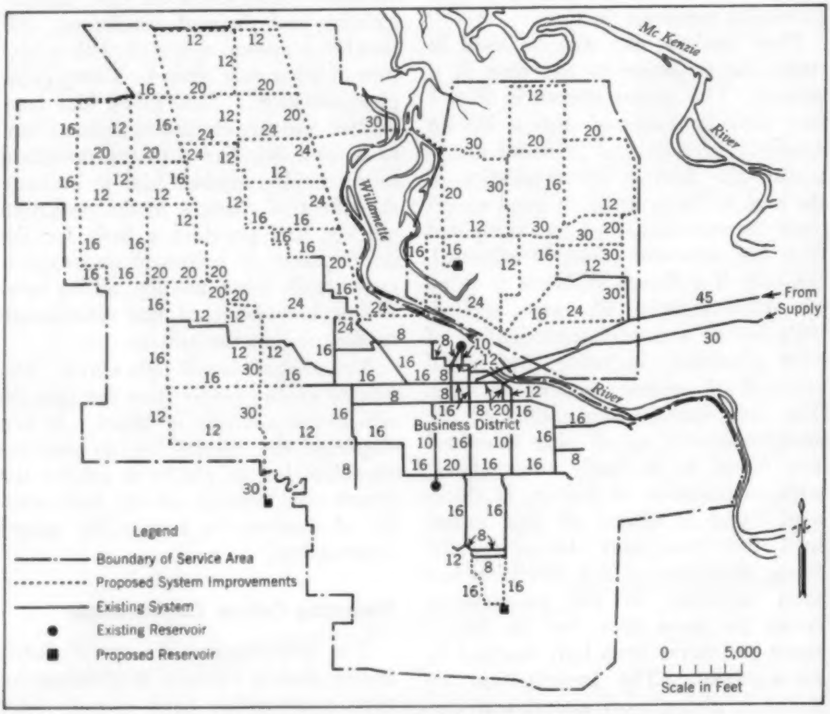



**Fig. 3. Distribution System Development at Eugene, Ore.**

*Numbers by pipelines indicate diameter in inches.*

sary for increasing the supply to an area. The development of a priority system of improvements indicating which areas are most in need of development allows the allotment of funds on a practical basis. It is also possible to estimate the storage volumes necessary for peaking purposes,

Often the hand method of analysis is adequate. The questionable accuracy of the input data does not justify analysis of extreme accuracy.

Probably the best use of accurate distribution network analysis is in the planning of immediate improvements. Predictions of demand a year or two in

and to establish the proper location of storage within the system.

Any development of a plan for expansion of a distribution system must be flexible because of the uncertainty of the future. It must allow for the addition of large individual demands at certain points where the zoning rules or the topography indicate that such development might occur. It is not economical, however, to build oversized lines just on the chance that they may someday be needed. This type of planning, though difficult, can avoid needless expense in the future. Economic comparisons of different methods of developing the distribution system can be made in advance. Thus the best solution from the economic and practical standpoint can be adopted.

Flexibility in future planning is illustrated by the development of distribution system extensions for Eugene, Ore., some years ago (Fig. 3). The principal portion of the city is located on the south and west sides of the Willamette River. The existing mains lying in this portion of the city required enlargement, as the service area was extending to the north along the west side of the river. As the supply was from the east, the immediately apparent solution was to relay or parallel existing mains through the most congested portion of the business district. Such construction would have been very expensive. The possibility of laying a main on the opposite side of the river for a portion of the distance and then crossing and connecting to the existing distribution system was investigated by distribution system analysis. The results indicated this to be a satisfactory solution to the problem, and economic comparisons indicated that the line on the north side of the river would be much less expensive, despite a difficult river crossing. Development north of the river was also anticipated if a new line was located there, and the final plan provided for two lines in that area, the second to be built as needed. This gave the system development plan flexibility. Construction of the 24-in. line north of the river resulted in considerable improvement in the distribution system pressures at a much lower cost than would have been possible by the increase of main size through the existing built-up portion of the community.

## Conclusion

Putting peak demand data to work in operation and design presupposes the existence of reliable demand data. Such data are not plentiful, but recent work by the Committee 4440—Water Use has developed much useful information. The statistical approach to the prediction of future peak demand offers a possibility for the solution of one of the problems that has heretofore limited the usefulness of network analysis when applied to water distribution systems.

The analysis of flow in a distribution network for peak demand conditions can be performed by the hand method originally developed by Cross, by the digital computer, or by the electric analog computer. The choice of method depends on the extent to which repeated analyses will be required and on the use that is to be made of the results obtained. Often exact results cannot be justified on the basis of the type of problem being studied, in which case the hand method, with skeletonization of the system, is indicated. For continued

analytic study of the same system, the electric analog method has advantages. For brief studies of different systems, the use of the hand or computer method is preferred. Although the example given does not indicate that analysis by computer is more economical than the hand method, the computer eliminates the drudgery of analyses performed by hand and frees the designer to apply his judgment and experience to the results. With the establishment of computer centers throughout the country, and with adequate programs for network analysis now developed, even the small system or the smallest design office can make use of computer analysis if it so desires.

The uses of network analysis are varied. It can be applied to the solution of operating problems from establishing pump operating schedules and programing reservoir refill during off-peak periods to studying the effect of corrosion on system capacity. The methods can also be applied to the development of plans for system expansion.

Even the computer is not capable of eliminating the basic uncertainties involved in predicting the capability of a water distribution system. Despite some claims to the contrary, computers cannot think, and the results obtained from any analysis are limited by the accuracy of the assumptions on peak demand, pipe friction and other variables involved in the problem. Analysis is a valuable tool, but it is a tool only, and does not replace judgment and experience.

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# Dual Water Supply for Seattle

*J. Ray Heath*

*A paper presented on Jun. 7, 1961, at the Annual Conference, Detroit, Mich., by J. Ray Heath, Supt., Water Dept., Seattle, Wash.*

SINCE 1901 Seattle has depended entirely on one source of supply, the Cedar River. Before then the city was supplied by private water companies from springs and streams in the forest-covered hills that are now occupied by the homes of Seattle residents, and from Lake Washington, which is now partially within the city.

Before 1889, many citizens opposed bringing in Cedar River water, although the only treatment it required was minimum chlorine application. The other alternative for the growing community was further development of the Lake Washington pumping system, which would involve more extensive treatment. On Jun. 6, 1889, however, a fire proved the inadequacy of the city's water supply. The entire business section of the city was destroyed. This sparked the enthusiasm of the citizens, who voted in favor of a $1,000,000 bond issue to construct the Cedar River gravity supply.

## Cedar River Watershed

The city's Cedar River watershed is 143 sq mi in area, is 25 mi in length, and ranges in elevation from 535 ft at the intake to 6,000 ft at the crest of the Cascade mountains. The city of Seattle now owns 70 per cent of this area, and the balance is owned by the federal government and private concerns. By agreement, the city will acquire the entire area when the present growth of timber is removed, and will continue to operate it as a multiple-use unit in production of water, power, and timber. The annual yield of 35,000,000 fbm of timber provides enough lumber to construct 5,000 five-room homes each year. Proper construction of roads, good logging methods, and rigid sanitary and fire regulations prevent erosion or contamination of the water supply.

The entire area is closed to public entry. Only city employees engaged in water supply and power generation and the employees of the logging operators are allowed to enter. Constant surveillance by water department patrolmen is maintained.

Runoff in the area flows into Cedar River and Chester Morse Lake (Fig. 1). This lake has a capacity of 55,000 acre-ft. The porous soils of the area temporarily store the water that eventually flows into Cedar River through springs, sustaining the river's flow during the dry season.

## Transmission to Seattle

From Chester Morse Lake the water flows into a pool that provides additional storage as well as head for the city's first hydroelectric generation plant, which was constructed in 1904. Overflow from the lake, the pool, and the tailrace at the plant continues in

Cedar River to the supply intake 15 mi downstream (Fig. 2). Here it enters the supply mains, and flows by gravity 26.4 mi to the city.

In 1960, the maximum capacity of the delivery system was 232 mgd (Fig. 3). The maximum daily consumption, which occurred on Aug. 8, 1960, was 264 mgd. Excess demand is satisfied by distribution reservoir storage of 385 mil gal.

For most of the distance between the intake and the city, the supply mains are contained in a 66-ft, municipally owned right of way, but for years the water department has been concerned about the vulnerability of its water supply, because it was dependent entirely on the one source transmitted through the one right of way. In many places the supply is carried through more than one main, but a single main break endangers the other mains. An earthquake could rupture them all, or a falling tree or airplane could cut off the entire supply to the city. These are unpredictable dangers. Acts of war could also eliminate supply through direct contamination, fallout, or a hit by bomb, missile or airplane.

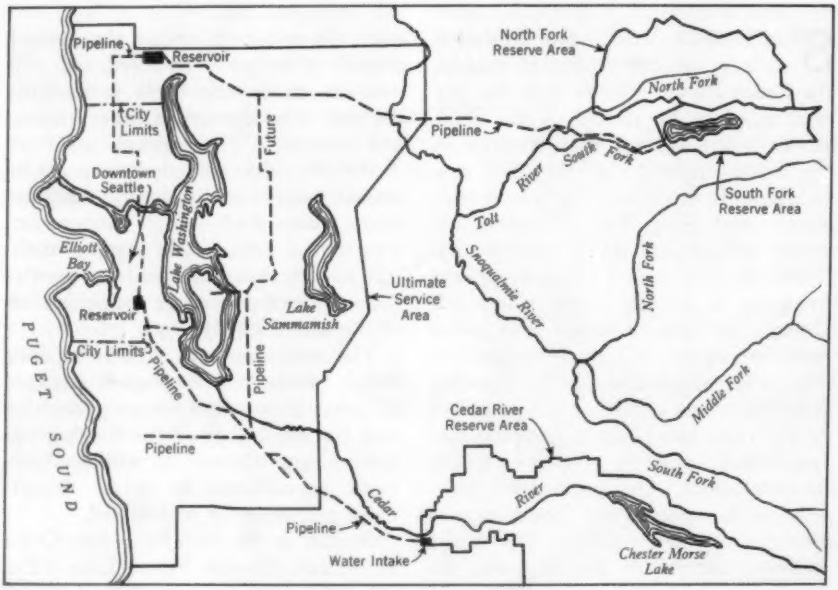


**Fig. 1. Seattle Water Service Area and Source Basins**

*Cedar River has provided Seattle's water since 1901. South Fork of Tolt River is being developed to provide a second supply; North Fork will be developed as need arises. Boundaries around basins enclose reserve areas.*

## Tolt River Supply

Acting on its concern about these dangers, the water department obtained water rights in 1936 on the Tolt River. Plans were made then

to develop that source when demands for additional water required it.

Consideration was given to several potential sources, but the feasibility and economy of the Tolt River development were most favorable. Further development of the Cedar River supply was considered, but the comparative costs favored the Tolt River development, which will provide the desired dual water supply to the city.

Planning for further storage and increased supply in the Cedar River watershed is proceeding to meet demands when needed. This supply can be doubled by constructing primary storage reservoirs upstream from Morse Lake.

The second river to Seattle, Tolt River, is now being developed. It will deliver water equal in quality to that of Cedar River early in 1962. This system is to be interconnected to the present supply, thus assuring water to all parts of the system in the event of disruption of service from either supply.

**Fig. 2. Intake on Cedar River**

*Large building is screen house in which traveling screens remove leaves and twigs from water before it enters aqueduct.*

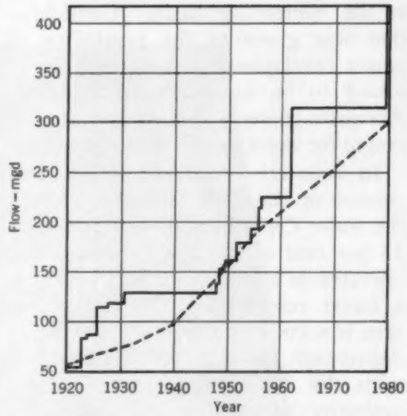


**Fig. 3. Seattle Water Department Supply and Demand**

*Broken line represents average demand; continuous line shows supply. The two increases in supply after 1960 will be accomplished by Tolt River pipelines.*

Presently under construction on the South Fork of the Tolt River is an earthfill dam to impound 58,000 acre-ft of water. This dam, 200 ft high and 1,000 ft long, requires approximately 1,750,000 cu yd of fill materials. The storage basin, 1,100 acres in area, is being cleared and grubbed.[1]

The first unit supply main, 54–66 in. in diameter, 30 mi in length, and having a capacity of 90 mgd, will be completed in 1961. It will run to a 60-mil gal distribution reservoir, also being completed in 1961. Another line of the same capacity will be constructed when required—probably by about 1980—when the North Fork of the Tolt River will be developed.

Besides adding a second supply, the Tolt River has a static head 200 ft above the Cedar River supply, which will reduce pumping to parts of the distribution system. In fact, it is necessary to dissipate 1,000 ft of head

at the controlling basin. Consideration was given to the possibility of power development, but this was determined to be unfeasible at the time. Adequate power will, however, be generated for water department operations.

In connection with operations and control of the Tolt River watershed, the water department is fortunate that 53 per cent of the area is owned and operated as a tree farm, 32 per cent is a forest reserve, and the rest of the area is owned by the city. The water department has a perpetual agreement with the lumber company, granting authority to operate the area as a closed watershed in the same manner as the Cedar River watershed is operated.

With two rivers to Seattle, each capable of meeting the present normal demand, the city is assured of additional water to meet the requirements of future growth and development.

Complete development of Seattle's two rivers will provide 650 mgd to the Seattle metropolitan area. This is almost 2.5 times the present maximum demand. The Seattle Water Department now serves practically the entire metropolitan area of Seattle. In addition to the city of Seattle, it serves 27 water districts, three cities and towns, and nine private and cooperative water companies. The department serves 750,000 people, 80 per cent of King County's population and 25 per cent of the population of the entire State of Washington.

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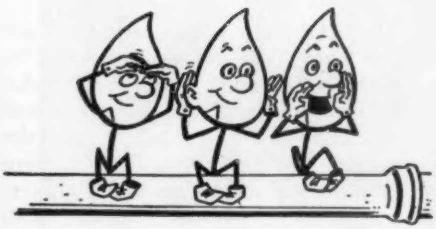
## Monthly Water Bond Interest Costs and Sales

*A report of the Chief, Basic Data Branch, Div. of Water Supply & Pollution Control, US Public Health Service, Washington, D.C.*

| Month | 1960–61 Net Interest Cost—*per cent* | | Total Bond Sales—*$1,000,000* | | |
|---|---|---|---|---|---|
| | General Obligation Bonds | Revenue Bonds | 1960–61 | 1959–60 | 1958–59 |
| Jul. | 3.99 | 3.93 | 133.1 | 17.3 | 39.0 |
| Aug. | 3.34 | 4.02 | 48.4 | 25.5 | 37.7 |
| Sep. | 3.82 | 3.75 | 18.8 | 16.6 | 14.3 |
| Oct. | 3.64 | 3.85 | 21.0 | 68.4 | 60.8 |
| Nov. | 3.36 | 3.86 | 18.4 | 36.3 | 42.5 |
| Dec. | 3.55 | 4.20 | 77.3 | 18.4 | 11.5 |
| Jan. | 3.88 | 3.70 | 37.8 | 21.2 | 28.3 |
| Feb. | 3.41 | 3.71 | 19.4 | 41.7 | 62.1 |
| Mar. | 3.47 | 3.48 | 102.8 | 19.5 | 57.0 |
| Apr. | 3.85 | 3.81 | 16.2 | 38.2 | 44.4 |
| May | 3.36 | 3.62 | 48.9 | 49.9 | 105.5 |
| Jun. | 4.09 | 3.86 | 80.4 | 111.4 | 50.3 |
| *Total* | | | 622.5 | 464.4 | 553.4 |



# Percolation and Runoff

**Quality water,** a prime requirement of the "improved water service" that AWWA has set up as its goal, is undoubtedly gaining here and there.

"Here," as a matter of fact, is probably the village of Marshalville, Ohio, a community of 650 population which recently installed a $40,000 plant to soften a raw water containing more than 1,000 ppm hardness. As the story was told on the front page of the Akron *Beacon Journal,* $40,000 is only the value of the plant; water-sewer-electric superintendent George Shaffer managed to save $22,000 by putting the plant together himself. The balance of the cost was raised by a village bond issue to be retired in 18 years with funds obtained through increasing average rates from $2 to $3.50 per month. And "there" are probably many other communities of all sizes performing equal heroics to provide "improved water service."

What we notice, though, are other signs pointing the other way. For instance, the water softener business sold 400,000 home units in 1960 and expects to sell 75,000 to 100,000 more than that in 1961, boosting total annual sales to $250,000,000. Of course, even in soft or softened water areas some families use home softeners to complete the job, but we would bet that an overwhelming majority of those new units are going into areas where the public water utility could do the basic job of softening at a very much lower cost to the community. For instance, too, the bottled water induspanies selling $30,000,000 worth last year, and ABWA—the American Bottled Water Association—expanding with the industry and helping it expand. Of course, even in areas where public water supplies taste good some people will demand bottled water, as in the Senate for instance, but we would bet that an overwhelming majority of those who do could be weaned.

Just think of the "quality" that could be built in with, say, $200,000,000 of that $280,000,000 of "water supply money."

**Desalinization** now has 6 years and $75,000,0000 more of federal time and money—not to mention an almost unlimited call on commercial research and development effort—in which to "make the deserts bloom" and thereby to win for democracy some down-to-earth respect, at least by those who

(*Continued on page 36 P&R*)

(*Continued from page 35 P&R*)

have deserts. That obviously was in the minds of Congress when it passed and President Kennedy when he, on Sep. 24, signed the desalinization research extension bill (H.R. 7916). Certainly they weren't thinking about saving the nation from the fate of having to continue using its fresh water resources and, although they were undoubtedly considering cost, no one had yet even suggested bringing it down to the fresh water level of 5 cents per thousand gallons.

As a matter of fact, the cost of desalting appears to be such a mishmosh of "engineering estimates," arbitrary assumptions, and, on occasion at least, strategic misinterpretations so well "established" that it is difficult sometimes to remember that no one really knows what plant scale desalinization does cost. Some of the factors that must be, and have apparently not been, considered in evaluating present data are brought out by some of our correspondents (see P&R p. 48), but operating experience alone will be conclusive. And on that basis the continuation of the federal research program, regardless of how unimminent our need for its results, is welcome.

**One ignored cost of desalting** that must be given serious consideration, we understand, is the cost of brine or sludge disposal. And consideration we have, therefore, been giving it.

Having noted the nutritional claims made for sea salts by food faddists and having been impressed with the success of Milwaukee's sewage plant in marketing its sludge as "Milorganite," we had just invented "Freeportriment" and were about to make a deal with the Office of Saline Water when the American Medical Assn. and the Food and Drug Administration queered it. First Dr. Ogden C. Johnson of AMA's Council on Foods and Nutrition shot off his mouth to the effect that "the average American mixed diet, except for iodine and iron deficiency in certain areas, needs no bolstering with mineral sea salts," and that "such claims are invariably made by food faddists and quacks whose prime interest is in making money." And then FDA, in an action to stop marketing of the Atlantic Ocean in bottles as "fountain of youth" stuff, pointed out that "medical authorities long ago concluded that there were no health benefits obtained by adding sea water to the diet."

Distressed, but not discouraged, we are now working on the details of a plan for distributing "Instant Sea Water" primarily in inland areas where the delights of sea water swimming are not to be had. Again we are looking to assist the Freeport, Tex., desalting plant, expecting to package its waste as "Good Gulf Goo" which midwesterners will be able to place in a pool and then just add water for solid seashore satisfaction. Through such a product even those who had no pools could enjoy sea water baths in their tubs and as soon as the Wrightsville Beach, N.C., and San Diego, Calif., plants were underway, we could offer a choice of Atlantic-, Pacific-, or Gulf-type natation.

Of course, if the federal government proves to be stuffy about this kind of commercial approach and won't go along with our means of making a real dent in the net cost of desalinization, the sludge can always be dumped into the Great Lakes. Thereby, the wastes

(*Continued on page 38 P&R*)

(*Continued from page 36 P&R*)

would be adequately diluted before they found their back into the sea, Great Lakers would finally obtain the benefit of *real* swimming, and the nation's railroads would undoubtedly be rescued from their apparently imminent bankruptcy. Of course, the cities which now draw fresh water from the Lakes would have to install desalinization plants, but from the current pressure to make desalinized water available when we are using only 10 per cent of our fresh water supply, we assume that it *must* be better anyway.

Some things, we suppose, are better ignored.

**The compact is now on the road**—the Delaware River Compact, that is, providing for a partnership of the federal government and the states of Delaware, New Jersey, New York, and Pennsylvania in the development of the Delaware River. Approved by Congress and by the legislatures of the states involved, the plan calls for a network of nineteen dams and reservoirs providing about 45,000 acres of fresh-water lakes with 120,000 additional bordering acres for recreation. Progress of and plans for the compact will be a feature of AWWA's 82nd Annual Conference in Philadelphia next June.

**The bath** seems to have ebbed and flowed over the centuries from a social amenity to an occasional substitute for perfume to a private sanctuary for personal hygiene. Now, in addition, it has become a yardstick of national living standards, not to mention another American status symbol.

It was in Greek and Roman days particularly that bathing was performed socially. Then in the Middle Ages it retreated to privacy and people usually attempted to mask rather than wash away their odors. But as public water systems became more common, the habits of personal hygiene apparently grew with them until the progenitors of today's individual baths achieved a more and more sanitary and less and less artistic appearance.

Now, as suggested above, the bath has become a matter of as much public awareness as it has of private occupancy. Today, the United States boasts that five of six of its dwellings (about 48,500,000) have bathtubs or showers, and no less than seven in eight, hot and cold running water. But in France only 10 per cent of the homes have bathtubs or showers, only 30 per cent, hot water, and only 60 per cent, running water. Meanwhile, Poland is apparently much worse off and, though comparable statistics are not available, it is obvious from the objections of one Citizen Grajewsky that the town of Orneta, which has a population of more than 10,000, has only "a few dozen" bathtubs.

Were we to go one step further though and total not the number of homes with baths, but the number of baths, we would get involved in the matter of status. Certainly if the United States has baths in five of six of its dwellings it will be able to claim many more than one bath per family, for homes and even apartments these days wouldn't be caught dead with a single bath. Thus, in the town of Southfield, Mich., last June, more than 90 per cent of the people interviewed felt that two or two-and-a-half baths were absolutely essential in homes in the $25,000 range. We've

(*Continued on page 40 P&R*)

*(Continued from page 38 P&R)*

always wondered which half gets bathed in a half-bath, but presume that the balance is taken care of in the "pool."

And the pool is not only the real essence of "status" but the natural derivative of the social bath—and our statusians these days are wearing very little more than their antecessors did in entering the public tub. All of which means that the bath is ebbing again, and the last time it ebbed Rome fell—with a splash! But who cares about Gibbon when *Playboy* magazine offers a much more picturesque and promising outcome.

**Cheap water,** long a pet hate of ours, was something we found ourself having to swallow the other way, as administered by Gerry Remus, general manager of the Detroit water department. Although the first sip—the fact that the department "sells its invaluable commodity cheaper than any other major city in the United States . . . 70 gallons for a penny"—set our teeth on edge, we found ourself practically gulping at the news that the department's 1960–61 fiscal year earnings were $5,172,000, that all these earnings will be used to improve the system, that "service has never been at a higher standard," and that the 1-bgd system, which can provide more water than demanded by the 50 communities being served, is already being fortified by a new Lake Huron supply scheduled to be completed in 1967. To us, when we had finished drinking it all in, the story wasn't one of "cheap" water at all. Low cost water, yes! A wonderful bargain, yes! Water supplied by an efficient organization, yes! But "cheap" is for the birds!

*(Continued on page 44 P&R)*


The
modern
approach
CARUS

*(Continued from page 40 P&R)*

**Isador W. Mendelsohn** has returned to the United States following a 2-year tour of duty in Korea, as a civil engineer for ICA. He served as chief of the water supply branch, helping to build new systems and improve old sources of supply. In 2 years, eleven projects have been completed, increasing the average water supply from 18 gpd to 25 gpd. During this time the urban population served increased by approximately 1,000,000.






**Red water** these days seems as much a result of Iron Curtain activity as of just plain iron. For months in the Berlin crisis we have been hearing about water as a weapon against anti-Communistic protests. Meanwhile, in Moscow at an American exhibition of plastic products, water turned to be a weapon of capitalistic conquest as a Betsy Wetsy doll proved to be the hit of the show. And in London, Britain granted political asylum to water purification engineer Oleg Lenchevsky, senior research officer of the Water Supply Institute of Moscow. But the real red water deal came in the announcement of the Communist economic program for the next 20 years, noting that, by the end of this period, water will be provided free of charge in the Soviet Union.

Which should make it obvious that we are too close for comfort to Communism.

**'Air Force in Air Force Delinquency'** might have been the headline in Mount Clemens, Mich., earlier this year as the city council was considering ways and means of putting pressure on Selfridge Air Force Base to pay up $16,000 in overdue payments for water supplied to the base and the newly built Capehart Homes connected with it. Source of the delinquency was an increase in rates of which the Air Force never took cognizance. Through their Congressmen, the city authorities finally brought the Air Force to earth and received, if not payment, at least agreement to pay almost all the arrears. One would think that the Air Force, particularly, would be conscious of the fact that every drop must be paid for.

*(Continued on page 46 P&R)*

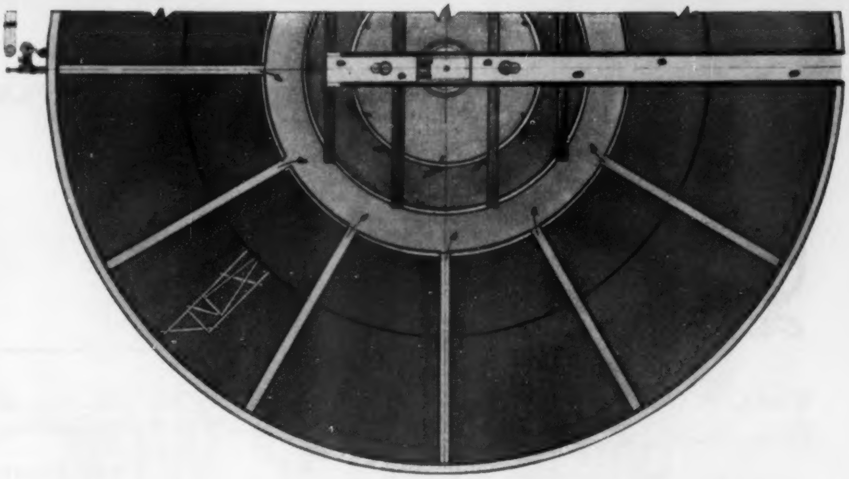
*(Continued from page 44 P&R)*

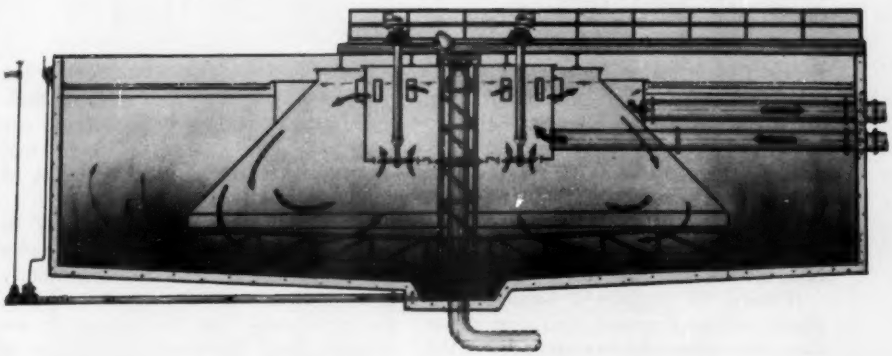
**A sound annual report** is what the city of Ypsilanti, Mich., presented to its citizens this year, putting its record on a record and delivering the $6\frac{1}{2}$-min, $33\frac{1}{3}$-rpm disc to every home. The recording opened with the mayor calling the roll at a city council meeting and went on from there with a professional narration of some city history and then the 1960 reports of each of the city departments, using appropriate sound effects, such as fire sirens, school bells, and, of course, running water. Total cost of the project, including planning and preparation, recording, production, and distribution, was a little over $900. This included $150 for a printed record jacket, which carried such additional information as a pie chart of the city income dollar, and the cost of refreshments for the Boy Scouts who made the delivery.

That this record on a record received record attention was no doubt partly due to its novelty. But the fact that the citizen could listen in at his own convenience, as well as the fact that once he put the record on not only he, but everyone within earshot heard it and heard it through, helped make it effective. All of which makes sound sound sound as a means of home communication.

**John W. Knutson,** who was assistant surgeon general and chief dental officer of USPHS since 1952, has accepted an appointment to the faculty of the new dental school at the University of California at Los Angeles.

*(Continued on page 88 P&R)*





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# Correspondence

## What Costs Water?

*To the Editor:*

A JOURNAL item (September P&R p. 37) shows justified annoyance at some of the hoopla surrounding saline-water conversion. My only complaint is that the Washington *Post* item you've quoted repeats the ridiculous assertion that the Freeport plant makes fresh water for $1 per 1,000 gal. Surely you know that this figure is an engineering estimate, not based on operating experience, and uses the Office of Saline Water (OSW) rate formula, which sets arbitrary (and minimum) costs for power and amortization, with no allowance for by-product brine disposal.

If one of the purposes of demonstration plants such as Freeport is to secure cost data, it's really a bit brazen to leave the impression that the cost is already known. But I have not seen the OSW make a serious effort to clarify this point for the more gullible members of the press. Presumably they are too occupied explaining the somewhat hasty shutdown at Freeport impelled by corrosion.

Evaporation control—to take just one example—can provide more cheap fresh water than any proposed technique for saline conversion. The key word is *cheap,* of course. There is not too much point in putting a large federal effort into an approach which will not add a significant increment of cheap water to our national supply.

More AWWA members should speak up about what really is needed for better management of our water resources, rather than merely feel pleased at the current attention their field is receiving.

CURTIS MICHEL

*New York, N.Y.*
*Sep. 25, 1961*

* * * * *

*To the Editor:*

The Association has stated that "the cost of treatment for fresh water, including softening, approximates 5 cents per 1,000 gal. It is this 5 cent figure that must be compared with the $1 cost of desalting."

I think that this comparison may be rather misleading, as it is only applicable in the special case of equal accessibility of the fresh and salt water; that is, where the fresh water and the salt water are obtained from underground sources of approximately equal depth and equal distance from the area of distribution.

It seems to me that the correct comparison, in the form of an example, is as follows:

*Cost of salt water:* Source, the sea. Loan and depreciation charges on capital investment for the sea water intake and the desalination plant, plus operating charges.

*Cost of fresh water:* Source, boreholes. Loan and depreciation charges on capital investment for the location and sinking and equipment of the boreholes, plus operating charges and treatment if necessary.

*Other factors:* Comparison of cost of capital investment for trunk mains including pumping which may be necessary, to bring the water from either the

(*Continued on page 50 P&R*)

## Correspondence

(Continued from page 48 P&R)

desalination plant to the distribution area or from the boreholes to the distribution area.

In Cyprus, the cost of water at the source (which is boreholes for most of the island), excluding any form of treatment, is approximately 45 mils per 1,000 gal, that is, with 100 cents equal to 350 mils, the cost would be 13 cents per 1,000 gal, as compared with the generally accepted figure of $1 per 1,000 gal for desalination.

I have been told that the Zarchin process (freezing) will produce fresh water at anything from 25 to 50 cents per 1,000 gal, but this has yet to be proved.

PHILIP H. PERKINS

*Nicosia, Cyprus;*
*Sep. 18, 1961*

* * * * *

*To the Editor:*

You have published figures that put the costs of treated water including distribution at only 12.3 cents per 1,000 gal and the complete cost of treatment, including softening, at 5 cents.

Had I been taking bets, I would have been sure that the total costs for treated, delivered water were at least twice this amount or more. Would it be possible for you to explain how generally representative this 12-cents figure is and how it was derived? Did it include a cost for raw water? If so what would be the range of the raw-water costs involved in this average calculation? I have put costs of raw water at 2½ cents per 1,000 gal, and have been accused of using much too low a figure.

HOWARD MENDENHALL

*Rend Lake Conservancy Dist.,*
*Benton, Ill.;*
*Sep. 1, 1961*

### Pitching Curves

*To the Editor:*

The September issue of *Compressed Air* magazine published an article on saline-water conversion which contained a table on consumption for the past 60 years and a forecast to 1975, using figures from the Water & Sewerage Industry and Utilities Div., BDSA.

| Year | Consumption *bgd* |
|---|---|
| 1900 | 40 |
| 1910 | 66 |
| 1920 | 92 |
| 1930 | 110 |
| 1940 | 135 |
| 1950 | 203 |
| 1960 | 312 |
| 1970 | 405 |
| 1975 | 453 |

This looked like valuable information to present to my board or to use in a speech, so I plotted a curve and filed it for future reference. I then thumbed through the September JOURNAL and found an article (P&R p. 37) which quotes some figures used by Peter Edson, agreeing with those I had just plotted. The article then proceeded to tear the figures apart.

Could anyone use my curve?

G. H. RUSTON

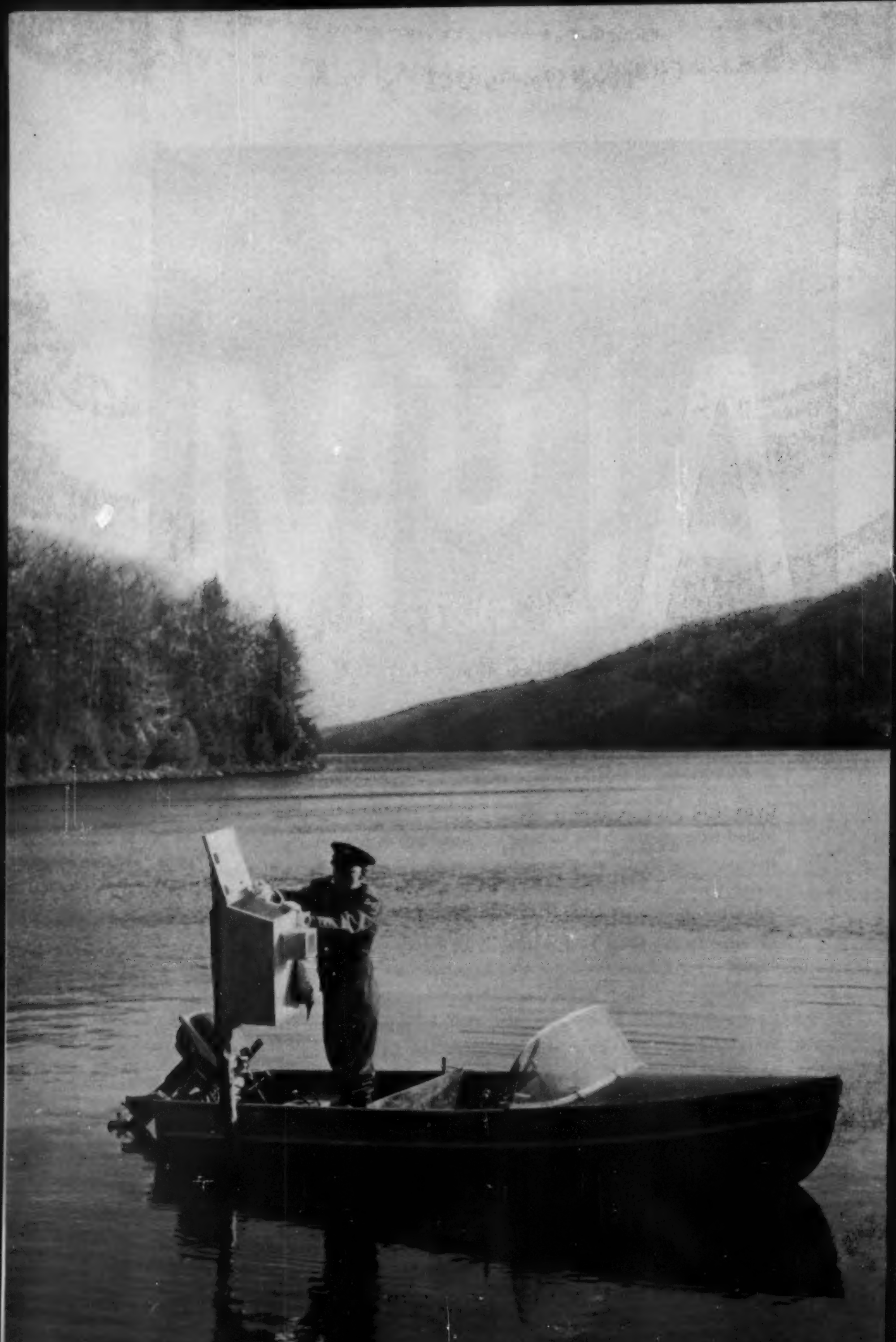
*Mgr., Racine (Wis.) Water Dept.;*
*Sep. 26, 1961*

### Shore Enough

*To the Editor:*

There were some pictures of installation of pipe in the July issue of the JOURNAL that make a safety-thinking person shudder. Specifically, they include the ones on page 891 and 894. The reason: shoring deficiencies.

(Continued on page 54 P&R)



## Correspondence

*(Continued from page 50 P&R)*

When it is necessary to place people in trenches that deep, shoring is needed. There is a man between the pipe and the trench side on page 891. The side of the trench is straight up and down, is about 8 ft deep, and has a top layer of pavement. Earth below pavement is notoriously dangerous because it will slough and fall. The earth is liable to have been previously disturbed and made more unstable. There may be some other utility installation not far back of the apparently firm and new cut that will make the new cut unstable. Backfill in streets today must be of permanently unstable nature because of the requirement to use sand for compaction improvement. These layers of sand can be as little as 1 ft back of a cut and not visible to the operators.

On page 894, Fig. 14 shows a deep trench with no shoring. Fortunately, there are no men down in the trench, but obviously they will soon be there.

AWWA is making progress in its safety program, but pictures like this would encourage many untrained water works supervisors to use the same type of precautions because they are "condoned" by AWWA. Keep up your good work and maybe we'll lick the problem someday.

ARTHUR J. WEBB,
*Safety Coordinator, East Bay MUD, Oakland, Calif.; Aug. 11, 1961*

### HEJ Scholar MS in CE

*To the Editor:*

It is with considerable pleasure that I can report to you that Mr. James Delbert Goff, a recipient of an AWWA Harry E. Jordan Scholarship in 1958, has completed his work and received his Master of Science in Civil Engineering degree. His thesis was on the water quality of the Trinity River in Dallas County.

I. W. SANTRY, JR.
*Southern Methodist Univ., Dallas, Tex., Aug. 28, 1961*

# Professional Services

# Professional Services

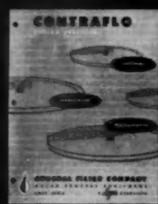
# *Professional Services*

# Professional Services

# NEW BULLETINS ON TREATMENT OF WATER, SEWAGE & INDUSTRIAL WASTE

AERATORS


FILTER PLANTS




CLARIFIERS


ZEOLITE SOFTENERS

**AERATORS**—Describes aerators for oxidation of dissolved iron and manganese, and for elimination of odors and gases. Explains and pictures forced draft aerators, pressure aerators and atmospheric aerators.

**FILTER PLANTS**—Lists problems of untreated water and offers solutions. Explains and pictures four basic water treatment methods for elimination of turbidity, minerals, gases, organic matter, and for pH correction.

**CONTRAFLO UPFLOW CLARIFIERS**—Pictures and describes five basic contraflo types for water softening and clarification. Explains application for industrial waste neutralization and recovery processes.

**"CR" ZEOLITE SOFTENERS**—Illustrates design and construction details of ion-exchange softeners for hardness removal; tells how to select proper units. Explains various types of regeneration equipment.

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# Condensation

**Key:** In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); NSA—Nuclear Science Abstracts; PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

## CORROSION

**The Influence of Movement and Temperature on the Corrosion of Mild Steel. I. Water Circulation Apparatus and Tests in Teddington Mains Water.** G. Butler & H. C. K. Ison. *J. Appl. Chem.* (London), 10:80 ('60). An app. designed for investigating corrosion due to flowing $H_2O$ at speeds up to 400 fpm and at temp. up to 70°C is described. The corrosivity of $H_2O$ is largely governed by its scale-forming properties, and an increase in both speed of flow and temp. promotes the deposition of a protective scale. The decrease of alky. due to scale deposition often results in a higher corrosion rate on specimens introduced into the system during the test.—*CA*

**Glass Drainlines for Disposal of Corrosive Wastes.** E. K. Lofberg. *Ind. Wastes,* 5:62 ('60). Pyrex glass drainlines are now available which are guaranteed against corrosion or joint leakage for the lifetime of the building. The glass pipe is resistant to all corrosive agents except hydrofluoric acid or hot alkalis. Corrosion-resistant Teflon is employed as the gasketing material. Glass piping is easy to assemble, readily dismantled, transparent, and everlasting. Overall cost is low. The use of glass pipelines has been approved by the Western Plumbing Officials' Assn.—*PHEA*

**Copper Corrosion and Its Consequences.** J. K. Aiken. *Prod. Finishing* (London), 12:90 ('59). Small amts. of dissolved Cu can produce serious consequences. Inhibitors such as benzotriazole and 2-guanidino-substituted aryl amidazoles are effective in preventing the dissoln. of Cu ions. They have been found useful in cooler, heat exchanger, and hydraulic systems.—*IM*

**Aluminum Withstands Corrosive Effects of Maracaibo's Warm, Oxygen-Rich Waters.** R. S. Dalrymple. *Oil & Gas J.,* 57:84 ('59). Aluminum pipelines and drilling structures of Alloys 6061 and 6062 show only minor corrosion from the water line to 30–40 ft below, and are virtually free of attack under this zone and into the mud on the lake bottom. Installations are by Creole Petroleum Corp., Superior Oil Co. of Venezuela, and Signal Oil Co. of Venezuela in Lake Maracaibo, where the water is warm and oxygen rich. Galvanic couples between aluminum and steel accelerate aluminum corrosion. Unprotected steel liner pipe is seriously corroded in the water but not in the mud.—*Corr.*

**Effect of Water on Mechanical Strength of Selected Ceramic Compositions.** W. J. Smothers. *J. Am. Ceram. Soc.,* 41:440 ('58). A study was made of properties of glazes and their effect on strength of certain glaze-body combinations and effect of atmosphere, vacuum, certain gases, glaze, and such organic liquids as coatings and coatings with water. Strength decreased with moisture in air and with water in coatings. It is suggested that a great part of strength imparted by so-called compression glaze may be due to moisture protection afforded by it. —*Corr.*

**The Role of Corrosion Inhibitors in the Treatment of Water.** E. L. Streatfield. *Metaux, Corrosion-Inds.,* 33:420 ('58). In a paper presented at a conference in Brussels, April 1957, the author discussed the causes of corrosion in industrial equip., the effect of softening the water, the mechanism of corrosion, factors affecting the extent of corrosion, and the use of corrosion inhibitors. Anodic, cathodic, and organic inhibitors were considered individually, and examples were given

(*Continued on page 66 P&R*)

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*when Halliburton cements them!*

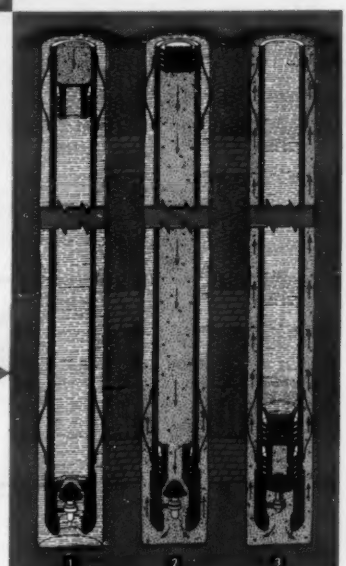
**The Halliburton Jet-Type Cement Mixer permits continuous blending of dry cement with water in controlled amounts to obtain consistent water-cement ratio throughout the job.**

The new well your contractor drills for you will probably be a good one . . . and *you* have to keep it that way. An important step toward continuous high yield from a water well is to construct the well *properly*. Proper construction should include cemented casing which help to provide:

* PROTECTION from migration of contaminated water in adjacent formations, and from polluted surface water.
* PREVENTION of bore hole cave-ins which can cut off water sources by filling the well bore or plugging the well screen.
* ISOLATION of the aquifer to be produced.
* PROTECTION of the exterior of well casing from corrosion.

For a better water well, get the *best* contractor . . . and to help keep your well trouble-free, longer, have him construct it properly, utilizing Halliburton's more than 35 years of experience in casing cementing.

The proven simplicity of *Halliburton's* Basic Cementing method




1. The Halliburton pump pressure forces the cement slurry into the casing behind the Bottom Plug which moves ahead of the slurry, and displaces well fluids in front of it to outside of the casing.
2. When the Bottom Plug lands in the Float Shoe, additional pump pressure ruptures the plug diaphragm, allowing the cement to pass through the end of the casing and up into the annular space between the casing and bore hole.
3. When the predetermined amount of cement has entered the casing, the solid Top Plug is inserted above it. Continued pumping of well fluid moves this plug down until it lands on the Bottom Plug, forcing the cement outside the casing. When pump pressure is released, the float valve closes, helping to prevent the cement from reentering the casing. The cement, thus held in position, sets to form a hard, permanent seal so necessary to the future protection of the well. After cement sets, the plugs are drilled out leaving the casing clear.

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**WATER WELL SERVICES**

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(*Continued from page 64 P&R*)

including the use of sodium benzoate, the use of triethanolamine and sodium mercaptobenzthiazole with ethylene glycole water coolants for piston engines, and the use of amines and quaternary ammonium compounds.—*PHEA*

**Protection of Trunk Pipelines Against Corrosion.** V. S. Turkin. *Stroitel. Predpriyatii Neft. Prom.* (USSR), No. 5, 5 ('58). Bituminous coatings used for protecting pipelines against corrosion show improved plasticity and resistance to freezing, without loss of strength, when 0.1–0.2% polyisobutylene or natural rubber is added. Addition of 1–3% polystyrene increases resistance to alkalis, and 0.3–0.5% of an antiseptic agent prevents bact. breakdown. Ground rubber in the amt. of 8–10% raises the softening point and improves the phys. properties. For bituminous coatings with kaolin as filler, the upper limit of protective potential is 1–1.2 v, and with rubber it may be raised to 1.5 v. In the vicinity of electric railway lines, protection against stray currents is provided by polarized drainage units of 150–500 amp. The production of glass fabric as a wrapper and of polyvinylchloride and polethylene coatings is being developed. —*Corr.*

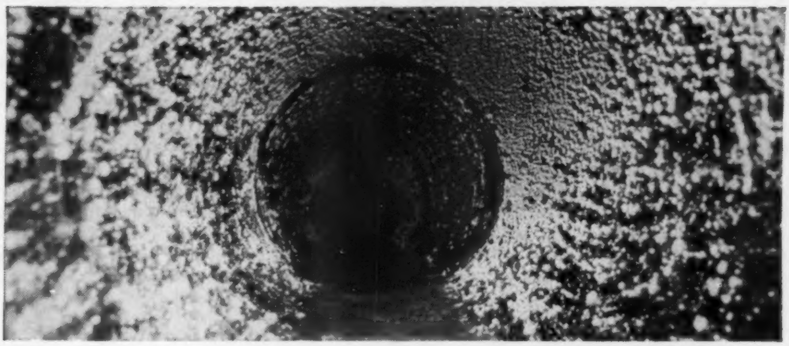
**Corrosion in Sour Water Strippers.** J. F. Mason Jr. & C. M. Schillmoller. *Corrosion,* 15:358 ('59). This paper discusses the several methods used for stripping foul waters, disposal of waste gas and water, types of corrosion experienced, and steps adopted to mitigate corrosion by inhibition, nonmetallic coatings, and alloy selection. Corrosion test results obtained in operating foul-water treating units also are presented.—*PHEA*

**Corrosion Tests by High-Temperature Water on Monocrystals of Aluminum of 99.99% Purity.** P. LeLong & J. Herenguel. *J. Nuclear Materials,* 1:58 ('59). Monocrystalline and polycrystalline speci-

(*Continued on page 68 P&R*)

Use CALGON® TG during the "critical" period—because

# TUBERCULATION ACTS FAST



The picture (taken 8 months after main cleaning) shows what happens to water mains during the "critical" period—the first few months after cleaning. The way to prevent this is to make sure that the freshly scored metal is protected *immediately*—and that means Calgon Composition TG, the treatment that forms a protective film *fast.*

The moment bare metal is exposed by cleaning, corrosion starts. The best way to make sure that corrosion of clean metal and in old pits does not get a head start is to get a protective film on the metal immediately. Put Calgon Composition TG right behind the scraper, so that this fast film-forming chemical can beat corrosion to the punch. It will also help disperse the removed corrosion products, making it easier to flush them from the main.

Calgon Composition TG has other benefits, too, when used in continuous treatment. (1) It makes "red water" complaints a thing of the past. (2) It is especially helpful in areas of low flow, and when temperatures go up. (3) Its greater efficiency keeps chemical costs down.

A letter or phone call will bring you more information on how Calgon can help. Or, a Calgon engineer, experienced in controlling water problems of all kinds, will be glad to make detailed recommendations on your specific problem.

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DIVISION OF **HAGAN** CHEMICALS & CONTROLS, INC.

(*Continued from page 66 P&R*)

mens of high-purity aluminum (99.99%), prepared from wrought metal, were subjected to corrosion by water at temps. higher than 100°C. By micrographic examn. the principal mechanisms of attack were identified and their kinetics studied. It is observed that: (1) a uniform film is first formed over the whole surface and, as previously shown, in the grain boundaries; (2) an irregular type of attack follows, accompanied by pitting; and (3) the latter first outlines a network pattern (trace of the dendritic solidification texture) and appears in the grain boundaries, hence the influence of the impurity distr. is revealed even in this high-purity metal. The growth phenomenon previously observed with polycrystalline sheet specimens during corrosion also occurs with monocrystalline specimens. As in the case of the air oxidation of zirconium, the metal creeps under the influence of the tension produced at the metal-oxide interface. Cold working tends to reduce the corrosion rate and attenuates or prevents a specimen growth; however, it does not appear to diminish the selective attack of the grain boundaries. Heat treatment of the cold-worked specimens at different temps. produces a progressive change in corrosion behavior, but it is not until the first recrystallized grains appear that the corrosion behavior again approximates that of fully annealed metal.—*Corr.*

**Corrosion of Inconel in 600°F Static Water.** G. E. GALONIAN & H. L. TYMCHYN. Knolls Atomic Power Lab., USAEC, Pub. KAPL-2047, Office of Tech. Services, Washington, D.C. ('59). A series of static autoclave tests was made to establish the corrosion rate of Inconel in various waters at 600°F and to det. its resistance to intergranular corrosion and stress-corrosion cracking. Tests of Inconel 132 welds and a bimetal weld-cladding joint between Inconel and Type 308 stainless steel were also made. The test results show that the two heats of Inconel tested possess a rate of metal loss up to 9 mg/sq dm-mo. No stress-corrosion cracking, intergranular corrosion,

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or selective attack of weld samples or cladding samples was found. Hydrogen-bearing water was the least corrosive and produced virtually no attack. The addition of ammonium hydroxide resulted in a smaller amt. of corrosion than that observed with neutral water. Some effects of heat treatment were evident in tests with ammoniated hydrogen-free water.—*Corr.*

**The Effect of Silicon on the Hot Water and Steam Corrosion Rates of Zircaloy-2.** M. D. Carver & H. Kato. Bur. of Mines, USBM-U1378, Office of Tech. Services, Washington, D.C. ('57). The effects of silicon in the range of 40–372 ppm on the resistance of Zircaloy-2 to the corrosive action of pressurized hot water and steam were investigated. The data were inconclusive that the corrosion rate in hot water varied with silicon cont. But the data showed the corrosion rate in pressurized steam to increase slightly with increasing silicon cont. in the range of 149–372 ppm silicon.—*Corr.*

**Remote Protection by Sprayed Metal Coatings on Steel.** H. Spindler. *Werkstoffe u. Korrosion* (Ger.), 9:278 ('58). Metal coatings—zinc, aluminum and aluminum-5% magnesium alloy—were sprayed on to selected areas of steel samples, and the protection afforded to the bare steel was studied and its extent measured by static and dynamic tests in natural and synthetic sea water. In alternating-immersion tests, remote protection was given only by zinc. A critical covered to uncovered area ratio is operative.—*Corr.*

**Antimony Plating on Steel and Zinc.** G. R. Schaer; W. H. Safranek; & C. L. Faust. *Plating,* 45:139 ('58). Anodic treatment of steel in acid soln. (preferably phosphoric acid) or iron plating was necessary before continuous, adherent antimony deposits could be obtained from the citrate bath. The former improved the corrosion resistance of antimony-plated steel but not that of zinc-plated steel. In salt-spray mist and in

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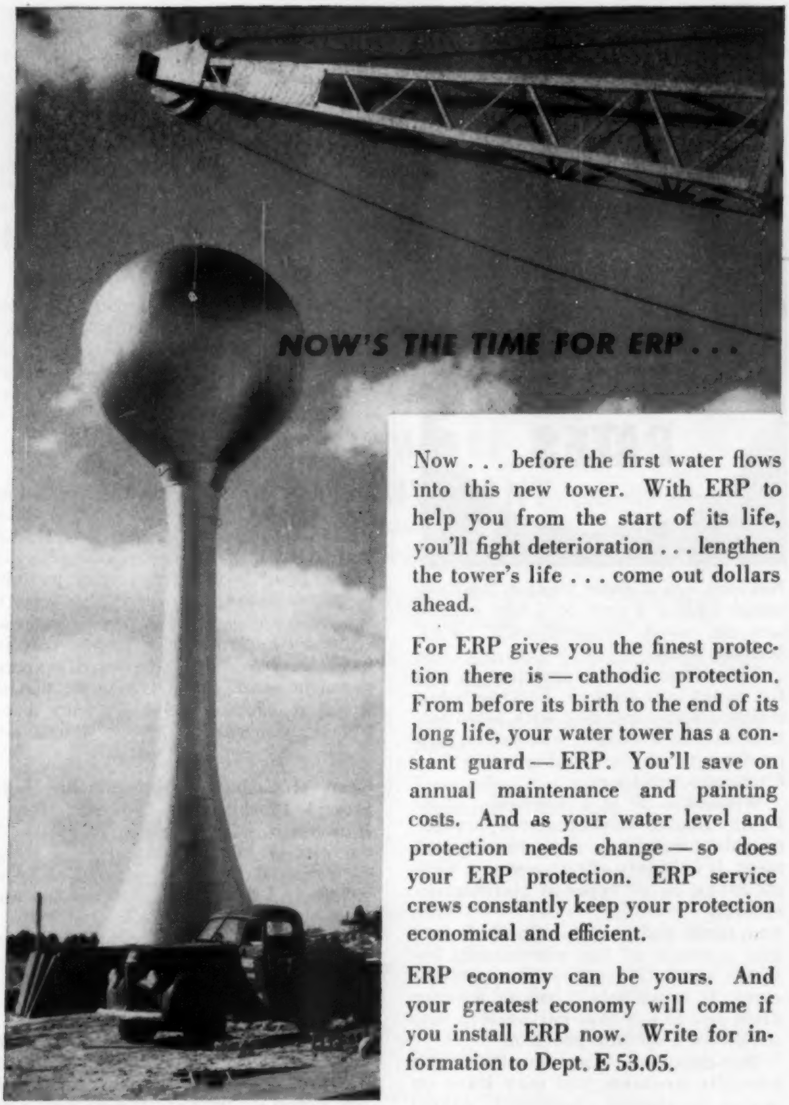


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*(Continued from page 70 P&R)*

air satd. with water vapor, antimony-plated steel showed a greater resistance to corrosion than did zinc-plated steel. Electroplating antimony on copper-plated or zinc die-castings is not recommended owing to blistering or peeling. The thinner antimony coatings produced on zinc by simple immersion in the citrate bath showed promise as an alternative to chromate coatings under outdoor-exposure conditions.—*Corr.*

**Sodium Salicylate as a Corrosion Inhibitor in Neutral Media.** E. V. BOGATYREVA & S. A. BALEZIN. *Zhur. Priklad. Khim.* (USSR), 32:1071 ('59). $NaC_7H_5O_3$ retards corrosion in distilled and tap waters for many steels. Min. protective concns. are given together with optimum temps.—*Corr.*

**Corrosion of 1100 Aluminum in Boiling $H_2O$ and $D_2O$.** J. E. DRALEY; S. MORI; & R. E. LOESS. Argonne Natl. Lab., USAEC Pub. ANL-6015, Office of Tech. Services, Washington, D.C. ('59). After an initial exposure period, corrosion rates of 1100 aluminum are approx. the same in water and deuterium oxide at 100°C. More corrosion was observed during the initial exposure period in water, but it is possible that this is only a reflection of the difference in control of the purity of the test water.—*Corr.*

**Costs of Cathodic Protection on Underground Pipelines.** G. REUTER. *Gas- u. Wasserfach.* (Ger.), 100:857 ('59). That the cost of cathodic protection is cheaper the earlier it is applied is indicated by calculated cost data for German gas and water pipelines, total length 224 km., protected by magnesium anodes, and for pipelines of total length 217 km., protected by impressed current installations.—*Corr.*

**Formation and Properties of Passive Films on Iron.** M. COHEN. *Can. J. Chem.*, 37:286 ('59). This is a study of a unified mechanism for the formation of passive films on iron in aqueous solns., together with the effects of water, oxygen, and oxidizing and nonoxidizing ions. The gamma-ferric oxide film is formed first by oxidn. of water-formed magnetite, while further thickening of the film occurs by oxidn. of diffusing $Fe^{++}$ ion at the water surface of the oxide film.—*Corr.*

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**Nonmetallic Coatings for Protecting the Tanks in Tankers Against Corrosion.** V. A. Bershtein & B. L. Krasil'shchikova. *Sudostroenie* (USSR), No. 3, 38 ('59). An evaln. of oil-free paint and varnish coatings in tanker cargo compartments for protection against attack by petroleum products and sea water showed that epoxide resin-based coatings have best resistance. Also investigated were aluminum paint and ethynol varnish with aluminum powder or iron oxide, bakelite varnish with 20–25% aluminum powder, and various primers, enamels, and varnishes. The compartments used, rarely if ever carried water ballast.—*Corr.*

**The Internal Cathodic Protection of Large Steel Pipes Carrying Sea Water.** J. H. Morgan. *Corrosion,* 15:417t ('59). The author discusses theoretic and practical aspects of internal cathodic protection for preventing corrosion of large steel pipe carrying sea water, and considers the costs of the process. At present the most economic method of protection seems to involve the use of a cheap, readily applied coating of reasonable resistance and cathodic protection from point anodes mounted at or near the center line of the pipe.—*WPA*

**Silicate as a Corrosion Inhibitor in Water Systems.** H. L. Shuldener & S. Sussman. *Corrosion,* 16:126 ('60). The development of a simple, economical proportional-liquid-feeding device for distributing sodium silicate in domestic water pipe permitted effective and widespread use of this inhibitor. For the past 32 years, it has been used for protection of galvanized iron, galvanized steel, yellow brass, and copper water piping in thousands of buildings in East Coast cities which have corrosive water supplies. Properly controlled, silicate treatment has elimnd. rusty water, maintained satisfactory flow rates, and minimized failures due to pitting and to clogging by corrosion products. Comparative field experiments have demonstrated its effectiveness. Most cases of poor results when using a silicate inhibitor have resulted from improper feeding by dosing methods, piping defects, poor plumbing design or fabrication, or improper operation of the water system, particularly with respect to lack of hot-water temp. control. Studies of the protective mechanism have shown that it involves formation of a thin film containing both silica gel and an absorption compound

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of silica and the metal hydroxide. Further basic studies are desirable for understanding the respective roles in protective film formation of alkalinity and silica in natural waters as compared to those in added silicate.—*PHEA*

**Corrosion of Nonferrous Metals: I and II.** *Bldg. Res. Sta. Dig.*, Nos. 110 and 111 ('58). Information is given on factors affecting the corrosion of lead, copper, zinc, and aluminium, and possible methods for preventing corrosion, including corrosion by acid rain water. Aluminium can be used for pipe to carry rain water, but cannot be recommended for water supply and waste water pipe. The use of nonferrous metals in water systems is considered, and the causes of corrosion of various sections of the system are tabulated. —*WPA*

**Prevention of Corrosion in Hot and Cold Water Systems.** J. J. Dwyer et al. *Am. Ry. Eng. Assoc., Proc.*, 61:285 ('59). Chem. causes and mech. design are considered. Chem. treatments are described and details of required dosages given for the various neutralizing and film-producing amines, with a description of the anal. methods available for control.—*CA*

**Stress Corrosion of Stainless Steel and Boiler Water Treatment at Shippingsport Atomic Power Station.** W. J. Singley et al. *Proc. Am. Power Conf.*, 21:748 ('59). Metallurgical examn. of tubes removed from the steam generator identified the failures as stress-corrosion cracking. Lab. tests indicated the failures were caused by caustic stress corrosion. The situation was corrected by increasing the $PO_4^{---}$ feed (added as orthophosphate) which in turn facilitated the maintenance of the proper $PO_4^{---}$-pH balance.—*CA*

**Sodium Silicate as a Corrosion Inhibitor in Gas Holders.** P. G. Clements & F. R. Jackson. *Gas J.*, 297:106 ('59). An investigation, carried out to study the effect of adding sodium silicate as a corrosion inhibi-

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tor to gas-holder water, is described. During a period of 13 months, steel test panels were hung in a silicate-treated holder and an untreated holder acting as a control, and removed at intervals for examn. The final results, though not conclusive, suggest that the life of a holder would be increased by using silicate. In the case of unpainted steel, an increase in life of as much as 30–60% was indicated. Furthermore, it was noticed that the silicate treatment markedly reduced staining of the paint work by red water. This may, in some cases, be more significant than actual corrosion inhibition; further work is to be carried out on this aspect.—*IWPA*

**Prevention of Corrosion of Steel Structures in Water Works.** W. Hauptmann. *Gas- u. Wasserfach.* (Ger.), 101:877 ('60). Satisfactory protection of Fe and steel requires complete scale removal, which is best accomplished by sandblasting. Oil-based paints are not satisfactory for underwater exposure. Properly made oil-modified resin paints are satisfactory. Bituminous paints also give good service, but are frequently replaced by paints of brighter color, esp. paints based on chlorinated rubber. Transition coatings (Sperrlack) between bituminous coatings and bright-colored paints are not entirely satisfactory and only a few colored bituminous paints are available. At present, such bituminous paints should be removed by sandblasting if colored paints are to be used. Painting should be carried out during the period when surface condensation rarely occurs and at a temp. above 20°C.—*CA*

**The Increasing Significance of the Corrosion and Boiler Deposits Problem.** P. M. Guldager. *Heizung u. Luftung* (Ger.), 26: 24 ('59). The problem of boiler deposits and corrosion is reviewed from the chem. viewpoint, and the effects of the preventive Guldager electrolysis process, which is an Al anodic protection process, are discussed. —*CA*

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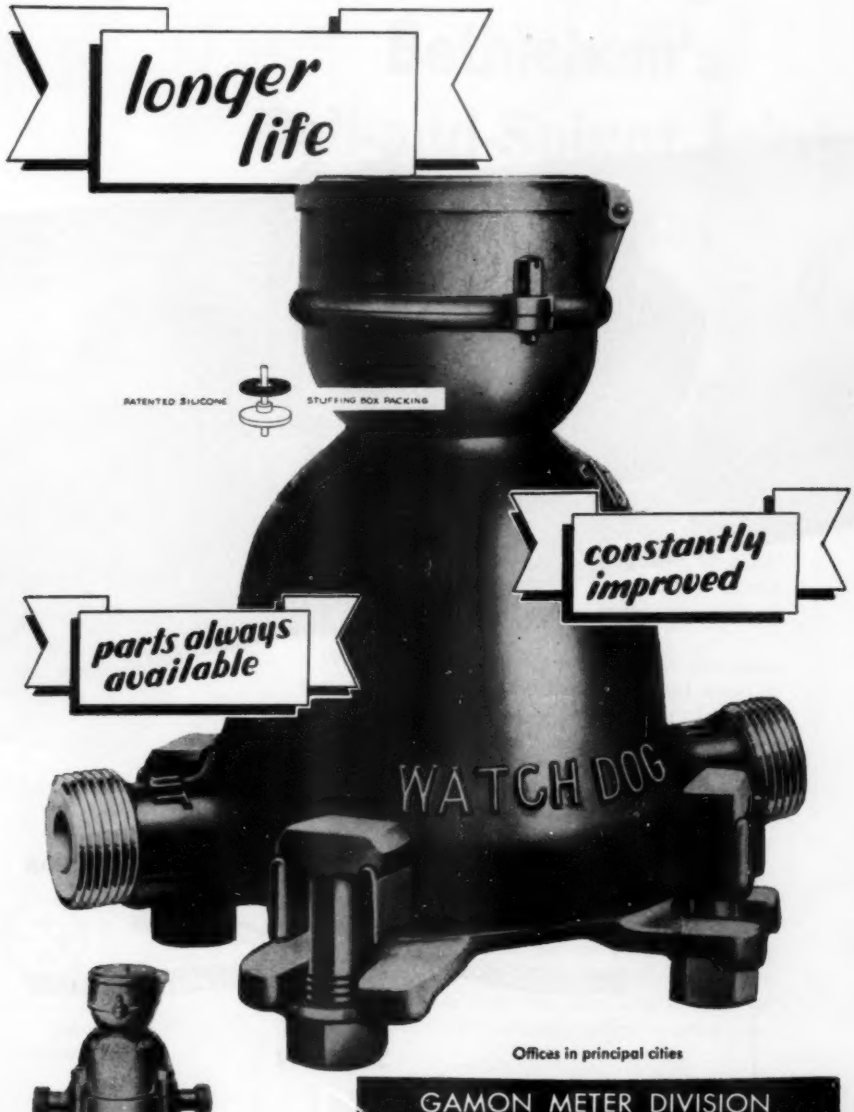
## BOILERS AND FEEDWATER

**A New System for the Completely Automatic Chemical Analysis of Boiler and Condensate Waters in Power Plants.** A. FERRARI & E. CANTANZARO. *Proc. Am. Power Conf.*, 21:722 ('59). The system consists of an automatic sampling unit, a proportioning pump, a const.-temp. dialyzer, a heating bath, a dual-beam ratio recording-type colorimeter, a ratio-type recording unit, and a voltage-regulator unit. Details of Si and P anals. are given. Ultimately, the analyzers will be applicable for detns. of Fe, Cu, chlorides, chromates, dissolved O, borates, hydrazine, Al, and Cl.—*CA*

**The Volumetric Determination of the Sulfate Contents of Boiler Waters.** K. GUNTHER. *Gas- u. Wasserfach.* (Ger.), 101: 1274 ('60). Sulfate in boiler water can be detd. rapidly by the following method: 40 ml of the boiler water is weakly acidified with 0.1*N* HCl. The water is then boiled about 5 min to drive off $CO_2$, after which phosphates are pptd. by adding a drop of 20% $Fe(NO_3)_3$ soln. and making the soln. ammoniacal with a few drops of 25% $NH_3$ soln. The soln. is then boiled to drive off $NH_3$. After cooling, the sample is transferred to a 50-ml graduated cylinder and made up to 50 ml. Approx. half of this soln. is filtered through a dry S. & S. No. 589 white-band filter into a dry 100-ml erlenmeyer flask. About 200 mg Ba oxalate is added, the mixt. boiled for a short time and again cooled to room temp.; after a few min it is filtered through a S. & S. No. 589 blue-band filter into a dry erlenmeyer flask, with the rejection of the first part of the filtrate; 10 cc of the filtrate is acidified with $H_2SO_4$, heated to about 80°C, and titrated hot with 0.01*N* $KMnO_4$ soln. A complete detn. takes about 0.5 hr. Calcn.: (ml 0.01*N* $KMnO_4$ soln. used − 0.7) 160 = mg/l $SO_4^{--}$. The 0.7 subtraction is a correction for soly. of the oxalate and for $KMnO_4$ used by water, free from reducing substances. With boiler water

*(Continued on page 86 P&R)*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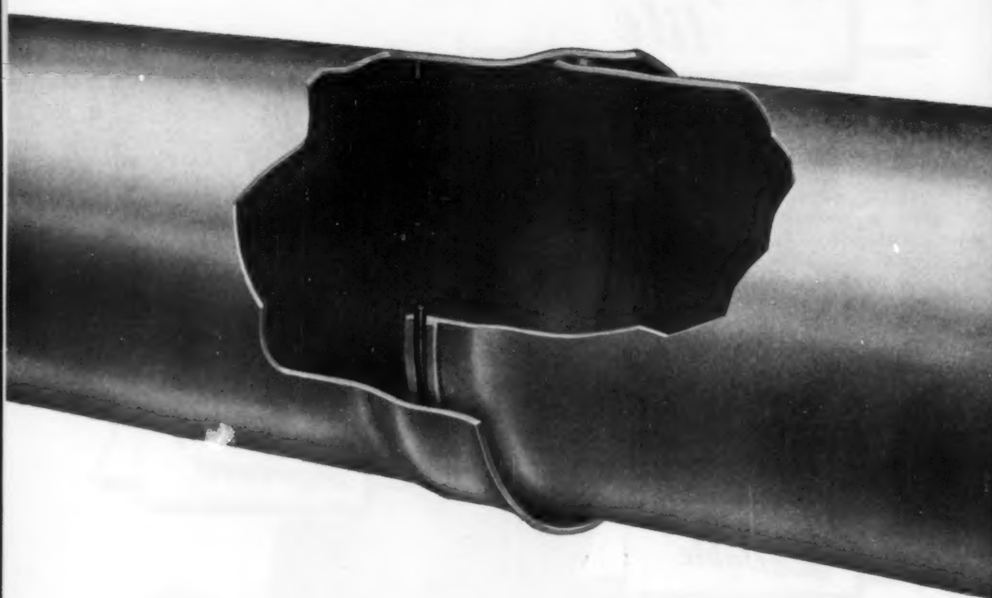


SECTION

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high in sulfate, interferences can be reduced by diln. of the sample with doubly-distd. water. In the presence of reducing materials, such as hydrazine, the water sample should be boiled with 5 ml 0.01*N* $KMnO_4$ soln. before other operations. This method requires approx. 250 mg/l sulfate; solns. with lower concns. should be concd. by evapn.—*CA*

**Determination of the Total Salt Content of Boiler Water From Electrical Conductivity.** J. A. de Nooyer & G. B. Smit. *Chem. Weekblad.* (Netherlands), 55:150 ('59). Pyrogallol is preferred to the gallic acid currently used as an auxiliary substance in this type of detn.—*CA*

**Demineralization of Water at the Alost Power Plant.** J. Berlo. *Tech. l'eau* (Brussels, 13:13 ('59). The author give a detailed description of the plant for demineralizing boiler feedwater for the power plant in Alost, Belgium. The water is treated with calcium hydroxide to ppt. carbonates, which are removed by sand filtration, and the decarbonated water undergoes ion exchange. The basic principles underlying ion exchange and the use of Amberlite resins are discussed.—*WPA*

**Treatment of Make-Up Waters in Cooling Towers.** V. Delaunay. *Genie chim.* (Paris), 83:37 ('60). The purposes of makeup water treatment are to prevent incrustation, inhibit circuit corrosion, and preserve the wooden towers. A treatment is described based on decarbonation of the $H_2O$ by acidifying to pH 5–6 with dil. HCl, followed by addn. of a chelating polyphosphate; NaClO is used for algal control.—*CA*

**Automatic Chemical Analysis of Aqueous Condensate in Boilers and in Electricity Plants.** A. Ferrari & E. Catanzaro. *Acqua industr.* (Italy), 2:30 ('60). Continuous automatic systems are described and shown diagrammatically for the anal. of boiler condensate, with particular reference to the detmn. of silica and phosphate, both by the molybdenum blue methods. The equip. is similar to that previously described for the continuous anal. of waste waters. —*WPA*

**Standby of Nonoperating Boilers.** R. T. Hanlon. *Modern Power & Eng.*, 54:98 ('60). Unless precautions are taken, serious corrosion occurs during out-of-service periods. If boilers are to be out of service for some time, the total alky. of the water before shut-down should be adjusted with NaOH, $Na_2CO_3$, etc., to between 400 and 500 ppm as $CaCO_3$, and a lignin derivative or tannin added. Cooling down should be at a rate of not more than 100°F/hr. The boiler should then be cleaned and later dried by a light fire. After sealing the boiler, moisture should be excluded by using CaO or silica gel within the boiler. For wet standby for shorter periods, a sulfite excess of 500 ppm should be maintained and a hydroxide alky. (supplied by NaOH addns.) of 2,000 ppm as $CaCO_3$, with sufficient lignin deriv. or tannin to give a dark brown color. The boiler must be maintained completely full of soln. (makeup with deaerated water). When superheaters are of the nondrainable type, it is desirable to add volatile neutralizing amine and hydrazine (instead of NaOH and sulfite) to provide a pH value of not less than 10.5 and a hydrazine excess of at least 500 ppm in the boiler water.—*CA*

**Boiler Water Treatment.** *Chem. Trade J.*, 146:1092 ('60). Boiler feed water for the Taswan Pulp & Paper Co., Auckland, N.Z., is obtained from the river Tarawera. The water contains about 290 ppm minerals with 60 ppm soluble silica, and plant has been installed to reduce the silica concn. to not more than 4 ppm and to lower the alky. Treatment comprises hot lime softening, and removal of silica by controlled addn. of magnesium oxide with recirculation of sludge. Any suspended matter carried over from the softening unit is removed in nonsiliceous pressure filters. Residual hardness is removed by treatment in hot sodium zeolite ion-exchange units. The water is finally treated in a deaerator to remove free carbon dioxide and to reduce the oxygen concn. to less than 0.005 cc/l.—*WPA*

**Modern Analytical Methods for Boiler Feed Water.** W. R. Jones. *Ind. Chem.*, 36:27, 34 ('60). The effects of various impurities in boiler feedwater are discussed, and analytic methods for their detmn. are described in detail. The impurities considered are carbon dioxide and carbonates, dissolved oxygen, silica, and copper and iron compounds; techniques for measuring the pH value and conductivity of boiler feed and makeup waters are included.—*WPA*

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**Insidious** is what we would call a recent advertisement in the Indianapolis *Star*, infectious, its philosophy, invidious, its technique. "Water's great for my bath, Mom [says the baby in the bath in the ad], but use 'Steam-Puff' for your ironing!" Steam-Puff, it appears is a "new miracle steam ironing fluid." And the ad goes on, thinking to fool us with flattery: "Don't use water in your steam iron. Change to new O-Cedar Steam-Puff today! It costs a little more than water (doesn't everything) but we're so sure you'll agree it makes ironing easier that we guarantee satisfaction or your money back."

In the next series I can imagine Marilyn Monroe in that bathtub, saying "Water's great for my petunias, Joe, but use champagne for my bath!" As for Joe, whether he's in the bath or not, I have no trouble imagining his saying: "Water's great for my boat, Marilyn, but use olive oil for my cooking!"

Next thing you know we'll be out of business.

**Homer P. Binder,** consultant in the fluid dynamics department of Allis-Chalmers Mfg. Co., retired on Jul. 31 after 50 years of service in pump engineering and sales. A former president of the Hydraulic Institute, he served as his firm's representative in AWWA since 1944.

**Practice what you preach**—that is, drink what you deliver—was the tenor of an article in the Chicago newspaper last spring, pointing out that, although 3,900,000 citizens of Chicago and 58 suburbs drink Lake Michigan water, those in City Hall who are responsible for delivering it to them prefer bottled water selling at more than a thousand times the price. The excuse given was that it would cost more to bring city water to the offices involved. Oh, to be a plumber!

**USPHS research grants** totaled almost $1,500,000 during the fiscal year ending Jun. 30, 1961. Established by Congress in August 1960, the program awarded 63 grants to 42 schools in 24 states and Puerto Rico.

**'Vagrant waters'** is a term that has about it an aura of romance, adventure, even mischief. And the fact that "vagrant water" may, according to Indiana law, be impounded by those who capture them on their property leaves us not a bit surprised. What does surprise us though is the fact that anything so imaginative, so understandable, could be the legal term for describing diffused [like confused] surface waters—that is, surface waters not following any logical course or lying within definite banks or boundaries. Probably the work of some vagabond lawyer.

**Louis A. Geupel** has retired from his position as an engineer in the office of the Assistant Secretary of Defense in Washington, and is now living in Evansville, Ind. A member of AWWA since 1922, he is a Life Member.

**The World Health Organization** will provide a limited number of short-term fellowships for the "improvement and expansion of health services" in the United States. Applicants must be engaged in full-time public health or educational work.

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The deadline for the receipt of applications is Jan. 1, 1962. Further information and application forms may be obtained from Howard M. Kline, secretary, WHO fellowship selection committee, USPHS, Washington 25, D.C.

**C. Elmer Clifton,** former sanitary engineer for Caird Laboratories, Troy, N.Y., died on Sep. 14 at his home in Round Lake, N.Y., at the age of 75. A graduate of Rensselaer Polytechnic Institute, he was associated with the Caird firm until his retirement in 1954. A member of AWWA since 1910, he was a Life Member.

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**Diaphragms, Pump:**
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**Engineers and Chemists:**
(See Professional Services)

**Evaporating Equipment:**
Ozark-Mahoning Co.
Permutit Co.

**Excavating Equipment:**
Charles Machine Works, Inc.

**Feedwater Treatment:**
B-I-F Industries, Inc.—Proportioneers
Calgon Co.
Hungerford & Terry, Inc.
Nalco Chemical Co.
North American Mogul Products Co.
Permutit Co.

**Ferric Sulfate:**
Tennessee Corp.

**Filter Materials:**
Anthracite Equipment Corp.
Carborundum Co.
General Filter Co.
Johns-Manville Corp.
Northern Gravel Co.
Permutit Co.

**Filters, incl. Feedwater:**
B-I-F Industries, Inc.—Proportioneers
Dorr-Oliver Inc.
Permutit Co.
Ross Valve Mfg. Co.

**Filtration Plant Equipment:**
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
Chain Belt Co.
Filtration Equipment Corp.
General Filter Co.
Golden-Anderson Valve Specialty Co.
Hersey-Sparling Meter Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

**Fittings, Copper Pipe:**
Dresser Mfg. Div.
Hays Mfg. Co.
Mueller Co.

**Fittings, Tees, Ells, etc.:**
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Smith-Blair, Inc.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

**Flocculating Equipment:**
Chain Belt Co.
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
F. B. Leopold Co.
Met-Pro, Inc.
Permutit Co.

**Fluoride Chemicals:**
American Agricultural Chemical Co.
General Chemical Div., Allied Chemical Corp.
Olin Mathieson Chemical Corp. (Mathieson Chemicals)
Ozark-Mahoning Co.
Tennessee Corp.

**Fluoride Feeders:**
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Co., Inc.

**Furnaces:**
Jos. G. Pollard Co., Inc.

**Gages, Liquid Level:**
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Hersey-Sparling Meter Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

**Gages, Loss of Head, Pressure of Vacuum, Rate of Flow, Sand Expansion:**
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Foxboro Co.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

**Gasholders:**
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

**Gaskets, Rubber Packing:**
James B. Clow & Sons
Johns-Manville Corp.

**Gates, Shear and Sluice:**
Armco Drainage & Metal Products, Inc.
James B. Clow & Sons
Mueller Co.
R. D. Wood Co.

**Gears, Speed Reducing:**
DeLaval Steam Turbine Co.
Worthington Corp.

**Glass Standards—Colorimetric Analysis Equipment:**
Fischer & Porter Co.
Klett Mfg. Co.
Wallace & Tiernan Inc.

**Goosenecks (with or without Corporation Stops):**
James B. Clow & Sons
Mueller Co.
Southern Pipe Div. of U.S. Industries

**Hydrants:**
James B. Clow & Sons
Darling Valve & Mfg. Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

**Hydrogen Ion Equipment:**
Photovolt Corp.
Wallace & Tiernan Inc.

**Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite**

**Ion Exchange Materials:**
General Filter Co.
Hungerford & Terry, Inc.
Nalco Chemical Co.
Permutit Co.
Rohm & Haas Co.

**Iron, Pig:**
Woodward Iron Co.

**Iron Removal Plants:**
General Filter Co.
Hungerford & Terry, Inc.
Permutit Co.
Walker Process Equipment, Inc.

**Jointing Materials:**
Johns-Manville Corp.
Keasbey & Mattison Co.

**Joints, Mechanical, Pipe:**
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

**Leak Detectors:**
Aqua Survey & Instrument Co.
Jos. G. Pollard Co., Inc.

**Lime Slakers and Feeders:**
B-I-F Industries, Inc.—Omega
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Permutit Co.
Wallace & Tiernan Inc.

**Locators, Pipe & Valve Box:**
Aqua Survey & Instrument Co.
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

**Magnetic Dipping Needles:**
Aqua Survey & Instrument Co.
W. S. Darley & Co.

**Meter Boxes:**
Ford Meter Box Co.
Rockwell Mfg. Co.

**Meter Couplings and Yokes:**
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Gamon Meter Div., Worthington Corp.

Hays Mfg. Co.
Hersey-Sparling Meter Co.
Mueller Co.
Neptune Meter Co.
Rockwell Mfg. Co.
Smith-Blair, Inc.

**Meter Reading and Record Books:**
Badger Meter Mfg. Co.

**Meter Testers:**
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.

**Meters, Domestic:**
Badger Meter Mfg. Co.
Buffalo Meter Co.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.

**Meters, Filtration Plant, Pumping Station, Transmission Line:**
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Hersey-Sparling Meter Co.
Simplex Valve & Meter Co.

**Meters, Industrial, Commercial:**
Badger Meter Mfg. Co.
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Buffalo Meter Co.
Fischer & Porter Co.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.
Simplex Valve & Meter Co.

**Mixing Equipment:**
General Filter Co.
F. B. Leopold Co.

**Motors, Electric:**
Allis-Chalmers Mfg. Co.
Worthington Corp.

**Paints:**
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

**Pipe, Asbestos-Cement:**
Atlas Asbestos Co. Ltd.
Johns-Manville Corp.
Keasbey & Mattison Co.

**Pipe, Brass:**
Anaconda American Brass Co.

**Pipe, Cast Iron (and Fittings):**
Alabama Pipe Co.
American Cast Iron Pipe Co.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

**Pipe, Cement Lined:**
American Cast Iron Pipe Co.
James B. Clow & Sons
Southern Pipe Div. of U.S. Industries
United States Pipe & Foundry Co.
R. D. Wood Co.

**Pipe, Concrete:**
American Pipe & Construction Co.
Lock Joint Pipe Co.

**Pipe, Copper:**
Anaconda American Brass Co.

**Pipe, Plastic:**
Keasby & Mattison Co.
Orangeburg Mfg. Co., Div. of The Flintkote Co.

**Pipe, Steel:**
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Southern Pipe Div. of U.S. Industries

**Pipe Cleaning Services:**
Ace Pipe Cleaning, Inc.
Centriline Corp.
National Power Rodding Corp.
National Water Main Cleaning Co.
Robinson Pipe Cleaning Co.

**Pipe Coatings and Linings:**
American Cast Iron Pipe Co.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Pipe Linings, Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Southern Pipe Div. of U.S. Industries

**Pipe Cutters:**
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Pilot Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.
Wachs, E. H., Co.
Wheeler Mfg. Corp.

**Pipe Jointing Materials; see Jointing Materials**

**Pipe Locators; see Locators, Pipe**

**Plugs, Removable:**
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

**Potassium Permanganate:**
Carus Chemical Co.

**Pressure Regulators:**
Allis-Chalmers Mfg. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

**Pumps, Boiler Feed:**
DeLaval Steam Turbine Co.

**Pumps, Centrifugal:**
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

**Pumps, Chemical Feed:**
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Inc.

**Pumps, Deep Well:**
Layne & Bowler, Inc.
Peerless Pump Div.

**Pumps, Diaphragm:**
Dorr-Oliver Inc.
Wallace & Tiernan Inc.

**Pumps, Hydrant:**
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

**Pumps, Hydraulic Booster:**
Peerless Pump Div.
Ross Valve Mfg. Co.

**Pumps, Sewage:**
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

**Pumps, Sump:**
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

**Pumps, Turbine:**
Layne & Bowler, Inc.
Peerless Pump Div.

**Recorders, Gas Density, $CO_2$, $NH_3$, $SO_2$, etc.:**
Fischer & Porter Co
Permutit Co.
Wallace & Tiernan Inc.

**Recording Instruments:**
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Hersey-Sparling Meter Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

**Reservoirs, Steel:**
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

**Sand Expansion Gages; see Gages**

**Sleeves: see Clamps**

**Sleeves and Valves, Tapping:**
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.

**Sludge Blanket Equipment:**
General Filter Co.
Infilco Inc.
Met-Pro, Inc.
Permutit Co.

**Sodium Aluminate:**
Nalco Chemical Co.

**Sodium Chloride:**
International Salt Co.

**Sodium Fluoride:**
American Agricultural Chemical Co.
General Chemical Div., Allied Chemical Corp

**Sodium Hexametaphosphate:**
Calgon Co.

**Sodium Hypochlorite:**
Wallace & Tiernan Inc.

**Sodium Silicate:**
General Chemical Div., Allied Chemical Corp.
Philadelphia Quartz Co.

**Sodium Silicofluoride:**
American Agricultural Chemical Co.
General Chemical Div., Allied Chemical Corp.
Tennessee Corp.

**Softeners:**
Dorr-Oliver Inc.
General Filter Co.
Hungerford & Terry, Inc.
Permutit Co.
Walker Process Equipment, Inc.

**Softening Chemicals and Compounds:**
Calgon Co.
General Filter Co.
International Salt Co.
Nalco Chemical Co.
Permutit Co.
Tennessee Corp.

**Standpipes, Steel:**
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

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Where remote control valve operation is desired, specify and use the G-A Cushioned Solenoid Operated Valve that automatically opens or closes on any type of electrical impulse. The operating sequence—whether on open or closed circuit—can be made to suit your requirements. Sizes 2″ to 36″

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Ford Meter Box Co.
Hays Mfg. Co.
Mueller Co.

**Storage Tanks: see Tanks**

**Strainers, Suction:**
James B. Clow & Sons
R. D. Wood Co.

**Surface Wash Equipment:**
Golden-Anderson Valve Specialty Co.
Permutit Co.

**Swimming Pool Sterilization:**
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Inc.

**Tank Painting and Repair:**
Koppers Co., Inc.
National Tank Maintenance Corp.

**Tanks, Prestressed Concrete:**
Preload Co., Inc.

**Tanks, Steel:**
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

**Tapping-Drilling Machines:**
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

**Tapping Machines, Corp.:**
Hays Mfg. Co.
Mueller Co.

**Taste and Odor Removal:**
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
General Filter Co.
Industrial Chemical Sales Div.
Met-Pro, Inc.
Permutit Co.
Wallace & Tiernan Inc.

**Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):**
Wallace & Tiernan Inc.

**Turbines, Steam:**
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

**Valve Boxes:**
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

**Valve-Inserting Machines:**
Mueller Co.
A. P. Smith Mfg. Co.

**Valve-Operating Units:**
B-I-F Industries, Inc.
Filtration Equipment Corp.
Wachs, E. H., Co.
Wheeler, C. H., Mfg. Co.

**Valves, Altitude:**
Allis-Chalmers Mfg. Co., Hydraulic Div.
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.

**Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:**
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Rockwell Mfg. Co.
R. D. Wood Co.

**Valves, Detector Check:**
Hersey-Sparling Meter Co.

**Valves, Electrically Operated:**
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.

**Valves, Float:**
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Rockwell Mfg. Co.
Ross Valve Mfg. Co., Inc.

**Valves, Gate:**
James B. Clow & Sons
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

**Valves, Hydraulically Operated:**
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

**Valves, Large Diameter:**
Allis-Chalmers Mfg. Co., Hydraulic Div.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

**Valves, Regulating:**
Allis-Chalmers Mfg. Co., Hydraulic Div.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Rockwell Mfg. Co.
Ross Valve Mfg. Co.

**Valves, Swing Check:**
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

**Venturi Tubes:**
B-I-F Industries, Inc.—Builders
Rockwell Mfg. Co.
Simplex Valve & Meter Co.

**Waterproofing:**
Inertol Co., Inc.
Koppers Co., Inc.
North American Mogul Products Co.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

**Water Softening Plants; see Softeners**

**Water Supply Contractors:**
Layne & Bowler, Inc.

**Water Testing Apparatus:**
LaMotte Chem. Products Co.
Wallace & Tiernan Inc.

**Water Treatment Plants:**
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Hungerford & Terry, Inc.
Infilco Inc.
Met-Pro, Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

**Well Drilling Contractors:**
Layne & Bowler, Inc.

**Well Reconditioning and Formation Testing:**
Halliburton Co.
Layne & Bowler, Inc.

**Wrenches, Ratchet:**
Dresser Mfg. Div.

**Zeolite: see Ion Exchange Materials**

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1961 AWWA Directory.